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THE
KANSAS UNIVERSITY SCIENCE BULLETIN.

Vol. V, No. 1—October, 1909.
(Whole Series, Vol. XV, No. 1.)

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THE DAKOTA-PERMIAN CONTACT IN NORTHERN KANSAS, . *F. C. Greene.*

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VOL. XV. No. 1

THE DAKOTA-PERMIAN CONTACT IN NORTHERN KANSAS.

BY F. C. GREENE.

Plates I to IV.

INTRODUCTION.

DURING the summer of 1906, while working on the University Geological Survey of Kansas, under the direction of Dr. J. W. Beede, the Permian-Cretaceous contact in Kansas, north of the Smoky Hill river, was mapped. The most of the northern third of the region was mapped jointly with Doctor Beede and the remainder mapped individually, in alternate stretches.

The region covered in this account lies in Washington, Riley, Clay, Dickinson and Ottawa counties, and is included in the Washington, Marysville, Clay Center, Abilene, and a corner of the Minneapolis topographic sheets of the U. S. Geological Survey. The area lies in the drainage basins of the Little Blue, Republican, Smoky Hill and Solomon rivers.

The topography is characterized by bold bluffs of the Dakota sandstone and smaller benches of the harder Permian limestones and shales. There is one peculiar feature of the topography throughout the region: northern slopes of the divides are generally steep, while the southern slopes are very gradual, and often without rock exposures. The effect is as if the land had been tipped to the south, or as if there had been an interruption of a southeastern drainage which turned the master streams to the east, thereby causing the streams to erode their southern banks.

In regions of the Dakota formation, this often results in an extensive series of low hills, composed entirely of loose sand, such as are seen in the vicinity of Abilene.

In the extreme northern part of the state, the country-rock is overlain by the glacial drift of the Kansan ice sheet. At the points where the contact crosses the Kansas-Nebraska line, the original topography and geology are obscured by drift, 60 to 100 feet in thickness, as observed from well borings.

GENERAL SECTION.

Pleistocene.—Glacial drift of Kansas sheet and loess (?) terraces.

Cretaceous.—Dakota formation, sandstones and clays.

Permian.—Limestones and shales.

Permian.—No attempt was made to distinguish between the formations of the Permian, but it was necessary to note such local aspects as would help in determining the contact line. There is everywhere an unconformity of considerable relief between the Permian and Cretaceous systems; which represents in time the Upper Permian, Triassic, Jurassic and Comanche Cretaceous.

The relief of this unconformity amounts, in places, to nearly 100 feet in the distance of a quarter of a mile. In one place (two miles northeast of Emmons, Washington county) there is a Permian monadnock which has patches of Dakota lying here and there on its sides, owing to erosion since Dakota times. This results in exposures of Permian above the level of the surrounding Dakota. Similar conditions on a smaller scale are found elsewhere.

Owing to this unconformity, the section of the Permian differs in places, the Permian having been eroded before the deposition of the Dakota to a lower horizon in some places than in others. The result of this is that the Permian is represented at the contact by different horizons, none of which are present over very large areas. At most places a series of thin-bedded limestones and shales was present at the contact, but in others a very porous limestone, evenly bedded red and yellow shales, or blue clay shales, represent the horizon of the Permian present at the contact. Over the whole area the Permian beds appear to be very evenly stratified.

The following section, taken from a cut on the Burlington railroad about two miles northwest of Hanover, Washington county, shows a typical succession of the Permian beds of that region:

10.	Limestone, thin-bedded, and yellowish shales	5 ft.
9.	Limestone, massive	6 in.
8.	Shales, calcareous olive-gray, with limestone about four feet from bottom	16 ft.
7.	Limestone, grading through marly concretions to marly shales	1 ft.
6.	Shales, marly gray	4 ft.
5.	Shales, red, evenly bedded, with occasional indurated bands; in the lower portion are two layers of very impure semi-crystalline limestone or dolomite, apparently thrown down by precipitation. There are also four or five very thin layers of greenish shales	15 ft.
4.	Covered	10 ft.
3.	Limestone, two layers, separated by bluish shale; upper limestone hard	3½ ft.
2.	Shales, olive, indurated	4 ft.
1.	Shales, yellow calcareous and argillaceous limestone	2 ft.
	Covered slope below.	

The character of the Permian from a little different horizon is shown in a section from the north bank of Mill creek, near the middle of section 13, Charleston township, Washington county:

7.	Covered.	
6.	Limestone, light buff, cellular, rather thin-bedded	8 ft.
5.	Shales, bluish and yellowish	13 ft.
4.	Limestone, blue, laminated, fossiliferous	4 in.
3.	Shales, bluish	3 ft.
2.	Limestone, hard, buff, fossiliferous	8 in.
1.	Shale, blue, and covered slope to water level	17 ft.

Cretaceous-Dakota.—The prominent bluffs of this formation are composed of a deep-red or brown, rather coarse-grained, ferruginous sandstone. For this reason the formation is often spoken of as the Dakota sandstone, but this is a misnomer, as the bulk of the formation is probably not a hard sandstone, but clays and shales.[1] Other exposures vary greatly. In fact, it is hard to imagine a formation of a more diversified character. It gives much evidence of being a shallow-water deposit, such as would be formed along shores and in small estuaries by delta deposits, etc. Both the nature of the deposits and the fossil content bear out this statement. The land mass was probably a short distance east of the present eastern outcrop, as the Dakota becomes more evenly stratified to the west. The fossils consist of the leaves of such genera as Quercus, Sassafras, Salix, Ficus, Protophyllum, Platanus, Betulites, etc., all land plants.

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[1] Gould. Trans. Kan. Acad. Sci., XVII, pp. 122-178. 1901.

Near the contact line the diversified nature is well shown. Yellow, red, brown and white sandstones are found, both consolidated and loose. These colors may be in separate layers or all in the same stone, in a space six inches square. In places a conglomerate predominates. In Charleston township, Washington county, about a quarter of a mile west of the line between sections 23 and 24, there are twenty-five to thirty feet of variegated, multi-colored clays, such as are typical of the Dakota a little west of Brookville, Saline county. The local name for this is "rainbow" clay, all the colors of the rainbow being jumbled into a variegated mass. There is no consistency in the structure in the easternmost outcrop of the Dakota. Within a quarter of a mile a road may cut through both a deposit of hard dark-red sandstone and a light-colored clay. In the sandstone cross-bedding is very much in evidence. In places large nodules of iron pyrites are found, while iron-oxide concretions of various sizes and shapes interest the inhabitants throughout the region.

The loose Dakota sands wash far down over the Permian and often obscure the contact.

As the sandstone is very porous, while the limestones and shales of the Permian are impervious, springs are found along the contact line and are helpful in locating it.

Pleistocene.—Glacial drift of the Kansan ice sheet. This formation overlies the five northern rows of townships in the region mapped. It is as diversified in character as the formations underlying it. Besides the sands and boulders of quartzite, greenstone, granite, etc., it is composed of fragments of Permian and Dakota rocks, the latter generally forming the bulk of the deposits. This is probably due to the fact that the Dakota formation extends some distance to the east in the region north of Kansas, thus lying directly in the path of the Kansan ice sheet. In the region of Hanover (and several other places) these materials have been cemented together into a conglomerate. Variegated clays and other clays, resembling those of the Dakota, have been deposited in places.

This causes some very perplexing problems in locating the contact in the drift-covered region. In the first place, it obscures the underlying formations over large areas, and in the second, it contains deposits of clay, sand and conglomerate almost identical with those of the Dakota. However, if there are any wells present, the water will be hard in the drift and soft in the Dakota sandstone.

Other Deposits of the Pleistocene.—In much of the region along the west side of Mill creek in Washington county there are fifteen feet of very sandy, jointed clays, gray above and brown beneath, overlying the plain sloping towards the creek. This deposit may be due to the changes which seem to have been made in the direction of Mill creek in glacial times. The topography and geology suggest the possibility that Mill creek once flowed southeast from Washington, with a large branch from the north joining it just east of Washington, while a small stream used the present outlet of Mill creek into the Little Blue river. There is a channel beneath Greenleaf, nearly 100 feet deep and filled with glacial debris, as shown by the wells supplying water to Greenleaf. Along the railroad between Washington and Greenleaf there are no exposures of rock in place, but as the region was not carefully studied this evidence is not conclusive. Glacial damming of this stream in the region southeast of Washington may have formed a lake which sought an outlet to the north in the present valley of Mill creek.

If these suggestions are true, it was probably in this lake that these deposits were formed.

West of the Republican river at Clay Center the river bluffs are terraces composed of loess-like material with calcareous concretions, and native rock below. They rise to a height of forty to sixty feet at the edge of the river bottom, and are higher here than farther back. There is, as a rule, a fair back slope of the terrace to the hills of the Dakota to the west, and the junction is usually occupied by streams or branches of them and the drainage is away from the river down the terrace, which has a maximum width of three miles.

It may be that this deposit is the same material as that which is known as "plains marl" in the western part of the state. In regard to the latter, Professor Haworth[2] believes it to have had the same origin as that of the Tertiary mortar beds, and thinks it probable that many of the properties of the plains marl are largely due to the action of wind.

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[2] Univ. Geol. Surv. of Kan., vol. II, p. 275.

In the region mapped the loess was found in valleys having a north-and-south direction. This may be due to the fact that a wind from the west, carrying the material, would deposit it in valleys lying north and south, while it would not accumulate in valleys having an east-and-west direction.

DISCUSSION OF THE MAPPING.

The mapping began at the Kansas-Nebraska line. Here the contact was concealed by 60 to 100 feet of drift. Just west of the Little Blue river, opposite Hollenberg, the Permian was exposed near the 1300-foot contour, while east of this town the Dakota rocks were exposed near the same level. Thus, in a general way, the contact is at the 1300-foot level between the state line and Washington west of the Little Blue. On the west bank of Mill creek there is a deposit of Pleistocene, covering the slope. The region is mapped as Cretaceous rock, though there is little doubt that it is material washed from the higher hills to the west. A tongue of Dakota extends north in the area between Mill creek and this river. If the suggestion that Mill creek formerly had its outlet to the south is true, this tongue would probably be an outlier.

On the east side of the Little Blue are outliers within six miles north and south of Hanover, but inside the boundaries of Washington county. South of Washington the contact rises nearly to the 1400-foot line, but west of that place pitches down, so that the Permian extends up Mill creek only two miles. The contact is found in the valley of Beaver creek, at an elevation of about 1375 feet. At Greenleaf, owing to the presence of the old channel noted above, neither Permian nor Dakota is exposed, but the former is only thirty feet below the level of the town a few miles east and west. Across this area the contact is dotted.

From Greenleaf to Clifton there is a continuous dip to the west. There is an outlier of Dakota in the vicinity of Chepstow, and it also extends south into the extreme northwest corner of Riley county, south of Kimeo. West from this point to Clifton the contact lies mostly in the northern row of townships of Clay county.

In the Republican valley the contact is concealed by a deposit of loess-like terrace material and alluvium, but a few miles east of Clifton it is found at the 1280-foot contour, and probably crosses the river about a mile southeast of Clifton. West of the Republican river the Dakota is found as a thin sheet on the terrace, as shown by well borings. Here the contact is at about the 1240-foot mark, but rises steadily to the south until the divide south of Manchester is reached, where a height of 1360 feet is reached. There is, however, a constant westward dip, so that the contact never extends very far west in the valleys of eastward flowing streams. In the region just described the contact passes near Idana, Oak Hill, Longford and Manchester.

East of the Republican river, in Clay county, the Dakota forms a large outlier about three miles northwest of Green. Here the contact is nearly up to the 1400-foot contour. From this outlier west to the Republican river the dip of the Permian is clearly and distinctly shown.

From Manchester to Abilene the Dakota lies on a narrow divide, but at its southern extension expands into a large area. In this area it is very thin, and disappears in a large expansion of sand hills, which may have originated from poorly lithified sandstone, or from stream or wind sediments.

From Abilene east to within three miles of Chapman, sand and sand hills occur on the north side of the Smoky Hill. There is much doubt as to the origin of these deposits. In this connection, the observations of Hay[3] in the vicinity of Junction City are interesting. He found sand hills near Junction City at or about the same level as those in the vicinity of Abilene. He says: "A more recent examination of the high-level sand dunes previously referred to revealed the fact that they are residual beds, resting on and abutting against undoubted outliers of the Dakota." Two areas of Dakota are shown on his map. These are only one-half of a mile west of the easternmost outcrops in Washington county, although the trend of the eastern outcrop of the Dakota is southwest throughout the state.

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[3] Hay. Geol. of Ft. Riley, etc., Bull. 137, U. S. G. S., p. 28.

CONCLUSIONS.

There is an unconformity of varying, but considerable, relief between the Permian and Cretaceous systems.

The eastern part of the Dakota sediments was deposited in shallow water along the shore and in estuaries and lagoons, as shown by the nature of the formation and the fossil content. Some of them may be of sub-ærial origin.

The shore-line of the Cretaceous sea was probably some distance to the east of the main body of the Dakota outcrop, as is shown by the presence of outcrops east of Hanover, Washington county, and in the vicinity of Junction City.

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FURTHER NOTES ON THE PUEBLO RUINS OF SCOTT COUNTY.

BY H. T. MARTIN.

(Contribution from the Zoölogical Laboratory, No. 188.)

Plates V to IX, and one text figure.

AT the annual meeting of the Kansas State Historical Society at Topeka in January, 1899, Dr. S. W. Williston read before that body a paper entitled "Some Pueblo Ruins in Scott County, Kansas," in which was fully set forth the results of the excavation of the ruins now known as Quartelejo, together with a list of the implements and weapons procured from the rooms which composed the old building. This paper will be found in the Kansas Historical Collections, volume 6, 1897-1900. Unfortunately it was not then possible to publish along with the paper the photographs and drawings of the ruins which were made during the excavation. In order to make the photographs and ground-plan drawing which accompany this paper as comprehensible as possible, the original description by Doctor Williston will be given almost verbatim. Since this account was based upon the field notes of the present writer, who made the excavations under the directions of Dr. Williston, its repetition here will be somewhat in the nature of a personal account.

DOCTOR WILLISTON'S ACCOUNT OF THE RUINS.

"The ruins are situated in the valley of Beaver creek (wrongly called Ladder creek on the map), in the northern part of Scott county, twelve miles due north from Scott City, and about ten miles south of the Smoky Hill river, as shown on the maps, precisely where the township line touches the most eastern bend of the creek. At this place the valley of the creek, which here runs nearly north, is less than a mile wide, surmounted on either side by high bluffs of Tertiary material. The immediate valley is excavated in the Cretaceous chalk. The result is that here, as elsewhere in western Kansas where like geological conditions obtain, the underflow through the Tertiary sandstones, over the impervious chalk floor, comes abundantly into the valley, furnishing a considerable stream of water. Perhaps no stream in the western part of the state offers more favorable conditions for irrigation than does this in its lower part. In the dryest years there is always an abundance of water in the stream, and in the deep pools along its course there are always many fish. About a half mile above the site of the present ruins, the Tertiary underflow comes to the surface along the side of a hill in such perpetual abundance that it is utilized in the irrigation of a considerable tract of land.

"These two facts—easy facilities for unfailing and extensive irrigation, and a fish- and beaver-producing, perpetually flowing stream—are undoubtedly explanatory of the location of the ruins at this place. The ruins are situated near the middle of the valley, close to the stream, and away from any possibility of ambush by hostile savages. They occupy a small knoll of ground, and, as first seen by us, consisted of a low, rounded heap of soil and stone, perhaps 75 or 100 feet in diameter, the soil wholly overgrown by buffalo grass. The rocks are the coarse sandstone of the neighboring hills. A small excavation had been made in the middle of this mound by previous explorers, perhaps two feet in depth and of a dozen square feet in area."

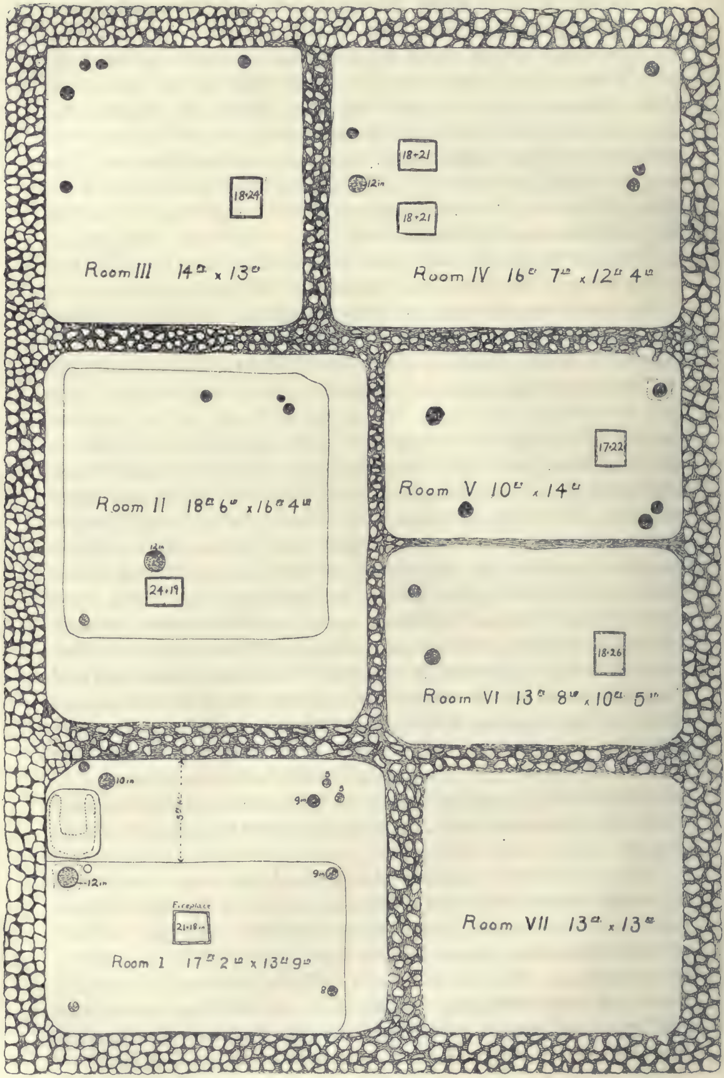
In conclusion, Doctor Williston says: "One fact is established from the explorations—the ruins are of Pueblo origin. Of this there can be no question. The plan of the structure is only such as the Pueblo Indians could have devised and carried out. It is not the work of white men, either Spanish or French, though it is very probable that both the Spanish and French may have occupied this and other structures at this locality at later times, or even contemporaneously with the Pueblos. The finding of an iron ax, of rude and primitive workmanship, it is true, indicates white men's skill. It is very evident, also, that the metal instruments were used by the occupants. Several of the manufactured articles show clearly the imprints of metal saw teeth.

"The origin of the ruins is of course not positively proven, yet I believe that concerning this there is scarcely a doubt that they represent the old fortified place known as Quartelejo, founded about 1650 by a party of Indians who fled from the oppression of the Spaniards, from Taos, in New Mexico. The only information concerning this place that I have so far been able to obtain is from the works of Hubert Bancroft, volume 17, on Arizona and New Mexico."

The following is the full description of the ruins as published in the Kansas Historical Collections by the present writer:

"In the excavation of the chief structure referred to in the cited paper, all possible care was taken to avoid mutilating the plastering with which the walls were covered, thus permitting the exact size and shape of each room to be ascertained. As now excavated, the walls are about two and a half feet in height. The structure measures fifty by thirty-two feet in size, and stood as nearly due east and west in its greater measurements as it would be possible to locate it with an ordinary compass. The outer walls were of heavy stone, from eighteen inches to two feet in thickness, and were cemented or grouted together, making the full measurement of the building about fifty-three by thirty-five feet. The building site, as has been described by Doctor Williston, was a slightly raised mound, about seventy-five yards from the bed of Beaver creek, which here affords an abundance of water for both irrigational and domestic use. By the side of the building there are two large, hollowed out places, which had probably been used for the puddling and mixing of the adobe employed in the construction of the building. The stone used in the building, all of which had been brought from the surrounding hills, was considerable in amount, and many single pieces are all that a man can lift.

"About 100 yards south of the main edifice there is evidence of several other smaller buildings, all of which must have been constructed of adobe alone, since no rock remains. These smaller structures, two of which were examined by us, yielded no utensils or other relics; nor could their size and shape be made out with certainty. Both of these buildings, as well as the large one, present evidence of having been destroyed by fire, whether as the result of some accident or by Indian foes one


Room III 14ft x 13ft
18×24
Room IV 16ft 7in x 12ft 4in
18×21
12in
18×21
Room II 18ft 6in x 16ft 4in
12in
24×19
Room V 10ft x 14ft
17×22
Room VI 13ft 8in x 10ft 5in
18×26
10in
5
5
9in
5ft 6in
12in
9in
Fireplace
21×18in
Room I 17ft 2in x 13ft 9in
8
Room VII 13ft x 13ft

cannot say, of course. From the fact that no human bones were found anywhere about, the probability of design is lessened. That the larger structure had been destroyed by fire there can be no doubt, since the adobe is burnt, and charcoal is thickly scattered everywhere; the stone and bone implements also all show evidence of fire. Rooms IV and VII, as I have designated them, show only slight evidence of the fire, and it is possible that one or both of these rooms had never been covered, and hence contained but little subject to destruction by fire. Room IV had portions of the rotted posts, evidently used as a ladder, remaining.

"Charred corn was found in every room except VII, in some places four or five inches deep. In room V there had been four or five bushels of this corn in a slightly hollowed out place at one side.

"About twenty-five yards north of the main structure there appears to have been three or four small structures, each separated a small distance in an east and west line parallel with the main building. These structures were apparently circular in outline, and were perhaps teepes.

"The most interesting room in the structure is the one I will designate as room I. Its dimensions were seventeen feet by thirteen feet and nine inches. It had a raised dais or platform on two sides, about six inches high; that on the west side five feet and three inches wide; that on the north side two feet. The wider one was doubtless used for sleeping purposes, and the narrow one as a bench. Very near the center of the room there is a box-like receptacle, formed of thin stone set edgewise. Like the others described further on, the bottom of this one was about six inches below the level of the floor, and its size was eighteen by twenty-one inches. It had been plastered at the bottom, and contained, when examined, a quantity of clean wood ashes. The receptacle may have been for the grinding and mixing of corn. In the southwest corner of the room there is a peculiar structure three feet nine inches in length by two feet and one inch in width, inside measurements, built of adobe. Its walls are eighteen inches high at the west end and twelve at the east end, the slope gradual from one end to the other. The walls, five or six inches in thickness, had been nicely rounded at the top. In the middle, and joined to the west end, is a small platform, about sixteen inches in length by twelve in width, raised about six inches above the bottom of the grooves which surround it. These grooves, shaped somewhat like a U, slope toward the closed end. This part was filled with ashes, suggesting that the use of the oven was for the baking of pottery. Near the east end was a large hole, twelve inches in diameter and eighteen inches in depth, covered with a flat rock. It contained nothing save fine dust.

"The walls and floors were nicely plastered. The plastering gave no indications of finger marks, but seemed to have been smoothed off with some instrument. Stones that might have answered such uses were found in the rooms. In this room was found a small pipe, decorated with horizontal markings. Here also were found a needle or awl for the sewing of hides, several arrow-heads, fragments of pottery, and bone needles. The remains of two posts, about eighteen inches apart, were found in the northeast corner, evidently for the uprights of a ladder for ingress and egress. Similar holes in like positions were found in the other rooms. There were no indications of doors or other openings in any of the rooms. The roof was evidently made of willow poles or brush covered with adobe, as large quantities of the latter show impressions of twigs.

"Room II was sixteen feet and four inches in width by eighteen feet six inches in length, and had both wall and floor plastered. The fireplace was two feet by one foot seven inches in size, and close by it was a hole twelve inches in diameter. On the east end there was a bench, as in room I, four feet two inches in width, and on the north side one two feet in width, while on the other two sides the width was but twelve inches, but raised to about ten inches in height. Close to the fireplace was found a grooved stone maul, ribs with marks of a saw upon them, arrow points, pottery, bone and stone scrapers, and a small pipe. On the ledge at the east end was found the half of an iron ax or wedge. The iron of course is much rusted, and the tool appears to have been split longitudinally and transversely by some mishap. It had a groove near the head, instead of an eye, for the attachment of the handle, after the manner of the stone axes of the aborigines. This room contained more charred corn than did any of the others.

"Room III was fourteen by thirteen feet in size, with plastered walls and floor, the corners rounded at the east end and square at the west. It had a fireplace eighteen inches by twenty-four, and a raised dais four feet wide at the west end. The holes for the posts supporting the roof and for the ladder were as in the other rooms. The plastering turned up about the posts showed that this work had been done after the roof had been placed over the structure. This room furnished grinders and several bone implements—scrapers and fleshers—made from the shoulder-blade of the buffalo and deer and antelope. The wall posts were rotted in the ground, and not burnt as in the other rooms, nor were the bone implements partly burned, as was the case with those in the other rooms. In this room, also, was found part of a musical instrument, a flute or flageolet, made from the wing bone of a large bird; also a bone implement with a serrated edge.

"In room IV fewer implements were found than was to be expected, for few marks of fire were visible. Owing to this, the room was in better condition for articles to have been preserved. It is just possible that the fire started on the south side, giving the occupants a chance to save most of their belongings from this room. Several scrapers, knives, also the small arrow points on plate I, Nos. 1, 2, 4, 5 and 12, 16, 17, 18, 19, 20, all of which are fine examples of workmanship, were found.

"Room V was the smallest in the building, being only ten by fourteen feet in size. It had well-plastered walls and floor, a fireplace seventeen by twenty-two inches in size, a large quantity of corn, arrow-heads, grinders, scrapers, pottery, etc. Close by the fireplace there was a hole in the floor covered by a flat stone that had been undisturbed. At its bottom was found half of a clam shell, which had been sawed lengthwise with a toothed saw, the tooth marks being very plainly apparent. In the northwest corner was a small oven, nine inches in width and sixteen in depth, excavated from the wall of the room and plastered throughout. It contained three or four inches of wood ashes in the bottom. In this were also found three oval and one square adobe bricks, about ten by fourteen inches in size, flattened above and rounded below. They may have been used in the baking of tortillas.

"Room VI was ten feet five inches in width by thirteen feet and eight inches in length. The level floor had been plastered, as also the fireplace, which was eighteen by twenty-six inches in size. There was a narrow partition between this room and room V, and since no indications of a ladder were found here it is possible that the two rooms had been connected. Several scrapers, of bone and flint, together with grinders, etc., were found here.

"Room VII, thirteen feet square, differed from all others in having no fireplace or plastered walls. Numerous bones of bison, deer, antelope, coyote, badger, etc., were discovered in this room. The only relics were bone and flint scrapers. Probably the room had been used as a sort of storehouse, and not for human dwelling.

"The pottery found was in part composed of plaster of Paris, possibly obtained from the crystals of selenite scattered over the chalk exposures in the vicinity. A number of ribs were found which had been smoothed at one end into a sort of spatula, and had probably been used in the making of pottery or in the plastering of the building. Coiled as well as smooth pottery was found, but only a single piece that showed evidence of decoration. Some of this pottery has been submitted to Professor Hewitt, of Las Vegas, N. M., who has given much attention to the work of the Pueblo Indians. He was of the opinion that all this pottery had been introduced from New Mexico, and had not been made in the vicinity of the building or village. Probably this is the furthest east that such pottery has yet been found. In one of the rooms were found several squash seeds; some between two pieces of pottery, in good condition, others much decayed."

In the above account by Doctor Williston, he very graphically described the locality, surroundings and natural resources in the immediate vicinity of the ruins, which he had visited in 1896, but unfortunately was unable then thoroughly to investigate. He also gave a number of important quotations from the works of Hubert Bancroft, an eminent writer on Arizona and New Mexico. These works treat largely of the early history of the Spanish in America, and contain important data relative to the position of the pueblo known as Quartelejo, and the condition under which this isolated post was first built and peopled. From the above-named works it appears that about 1650 a band of Taos Indians fled to the plains and fortified a place called Quartelejo. In the papers of the Archæological Institute of America, American series V, Hemenway Archæological Expedition, A. F. Bandelier, page 181, says: "In 1704 the Indians of the pueblo of the Picuries abandoned their village in northern New Mexico and fled to the plains, where they established themselves at a place called El Quartelejo. Superstition was, from all indications, the cause of this hasty movement." In a foot note he adds: "This flight of the Indians of the Picuries to the Quartelejo is mentioned in several documents. I quote here only the witchcraft trial, entitled '*Causa Criminal contra Geronimo Dirucaca, Indio del Pueblo de Picuris,*' 1713, MS., fol. 16, 17. The same document also fixes the date. In regard to the return from Quartelejo, it was effected in 1706 by Sargente Mayor Juan de Uribarri."

For some reason or other there appears to be a conflict as to the exact date of the settlement of the Indians at Quartelejo, yet both the above writers agree that the return to Mexico was effected in 1706. This would indicate clearly that both Bancroft and Bandelier were writing about the movements of one and the same band of Indians. Furthermore, it does not appear credible that the governor of New Spain would have allowed these discontented Indians to have stayed at Quartelejo from 1650 until 1704, a period extending over fifty years, without an effort being made to effect their return, and in all probability Bandelier's date of the founding of this isolated pueblo in 1704 is the more correct.

He further states that "in all probabilities the place got its name from the fact that these Picuries Indians made a temporary stay there." This is also intimated by Fray Silvestre Valez de Escalante in his letter to Father Agustin Morfi, April 2, 1778. After the evacuation of the pueblo in 1706 at the instance of Uribarri, another band of friendly Indians must have taken possession of and occupied the place for a number of years, for from Bandelier we learn that in 1719 Governor Don Antoni Valverde Cossio, having determined upon a campaign into the north and northeastern plains (a movement made chiefly against the Yutes and such of the Comanches as had joined them), penetrated as far as the Quartelejo, and even beyond. A part of Valverde's object was to secure the rancherias of the Jacarrilas against their foes. Part of these friendly Apaches lived at Jacarrila, forty leagues north of Santa Fe, and another band lived at Quartelejo. Again, we find that in the following year, 1720, Don Pedro de Villazur called at this pueblo on his ill-fated trip to the Pawnee village which is supposed to have been located on the Platte river, when all perished at the hands of the treacherous Indians. After this I have been unable to find the place mentioned by any other writers of early southwestern history. And it is more than probable that after the Pawnees had annihilated Villazur and his soldiers they also, to check the inroads and settlement of the Spanish and their allies, destroyed the Quartelejo, thus effectually clearing the whole country north of the Arkansas river. This would admirably account for the entire pueblo and settlement being destroyed by fire, as it undoubtedly was. From the position of the utensils and implements found, a very hurried departure must have been made from the main structure. Most of the meal-grinding apparatus found in each room appeared to be left in a group, as though just laid aside after use. This, and the finding of so much charred corn in most of the rooms, would surely indicate that no prearranged plan of evacuation had been decided upon. That the ruins are those of the Quartelejo mentioned by the old Spanish writers, to which conclusion Doctor Williston came after seeing the group of relics obtained, there can be no doubt.

Dr. F. W. Hodge, of the Bureau of Ethnology, says, in the American Anthropologist, volume 2, October and December, 1900, that he regards the discovery of the ruins as of great interest, that they are of typical pueblo fashion, and, in conclusion, says: "The former existence of this pueblo has been known to students of southwestern history and ethnology for a number of years, but not until the publication of the results of the investigation had its situation been known, and there is no reasonable doubt that the identification is correct, for pueblo architecture is intrusive in Kansas."

If the identification by Doctor Williston as Quartelejo is correct, then the exact locality of this pueblo, so often referred to by the old Spanish writers, and to which Don Juan de Archuleta journeyed, is assured, and as such should be of great value in assisting to prove more definitely that the localities designated by Brower and Hodge as the site of Quivera and Harahey are correct, and thus have some bearing as to the probable line of march of Coronado, and help to prove that he did cross the Arkansas river.

Brower says, in his "Harahey," page 27, volume 2: "When the final acceptance shall have been established that Coronado reached and crossed the Arkansas river and followed its course to the great bend, then the true site of Quivira and Harahey will have been finally reached and comprehensively understood."

By referring to a quotation given by Doctor Williston in his paper taken from the narrative of Fray Silvestie Velez de Escalante, April 2, 1778, translated "In the Land of Sunshine," we find that Don Archuleta found in the possession of the Indians of Quartelejo pieces of copper and tin, and that they said they had procured them from the Quivera pueblos, to which they had journeyed from Quartelejo.

If these Indians had visited Quivira as they claimed, and Quivira and Harahey was where Brower and Hodge have located it, northeast of Quartelejo, then the presence in the ruins of the sandstone arrow straighteners can be satisfactorily explained, and the possession of knives and arrow heads of the Harahey type and material does tend to prove they had communicated in some way with the Quivira settlement. The arrow straighteners referred to, and which were found in the ruins, are made of the Dakota Cretaceous sandstone.

The writer has found many arrow straighteners on the western Kansas prairie made by the plains Indians, within a few miles of the ruins, but these were all of a different and harder material. Dakota sandstone in any shape is intrusive in the neighborhood of the ruins, but a journey to Quivira by the Indians of the Quartelejo would take them directly through the outcroppings of Dakota sandstone which occur in Ellsworth, Barton and Rice counties, and enable them to procure and carry back with them this valuable acquisition.

In a previous paper the writer made mention of a peculiar U-shaped structure that looked like it might have been used for the baking of pottery, on the raised platform-like center piece, a photograph of which is shown on plate VI, fig. 3. This, Dr. F. W. Hodge, in the American Anthropologist of October and December, 1900, says is a typical pueblo grinding trough, and on the raised platform in the center was undoubtedly fixed the grinding stone.

The small fireplace and chimney built into the wall of room V is due to the influence of Spanish associations, for at this early date chimneys were unknown to the Pueblo Indians of New Mexico. The chimney leading to the roof was carried up the center of the wall between rooms V and VI, and was plastered inside, provision being made to allow for room for this by a thickening of the wall at this point. It is of course not known of what material the inner walls were composed, but from the amount of rock that had been removed from the ruins for building purposes by settlers the past twenty years, and the amount remaining at the time of the excavations, I think it is safe to presume that the whole structure, with one exception, was composed of rock. The wall separating rooms V and VI was entirely too thin to allow of being built of stone, and was in all probability made of willows woven together and plastered over. The division wall extended clear across the room to a height of eighteen inches, and although no opening for communication showed at this height, it is more than possible that these two rooms were connected by some opening in the division wall higher up, considering the fact that in room VI no post holes remained showing any indications of their having had a ladder for communication with the roof.

It is much to be regretted that out of the vast amount of material that has been collected in and around the 100 or more village sites enumerated in Brower's Harahey, not more than a dozen specimens have been secured for the University collection of archæological material. Yet Brower states that more than 10,000 archæological specimens have been gathered, and are deposited in the museum of the State Historical Society of Minnesota.

As a means of advancing the study of the earliest history of the state, and as an inducement to students interested in archæology and ethnology, scarcely could there be anything more valuable and important than a well labeled, systematically arranged series of archæological specimens collected from these historical old village sites of Quivira and Harahey, visited so long ago by Coronado and his followers.

I here wish to convey my thanks to Dr. C. E. McClung for his assistance in the preparation of this paper, and for his kindly advice and corrections.

In the near future a model of these interesting ruins, the first ever inhabited by white man in the state of Kansas, will be constructed and placed in the University museum.

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CONTENTS:

The Influence of Magnesium Sulphate on the Motor Cells of the Cerebral Cortex, . . *H. F. Hyndman and W. E. Michener.*

PUBLISHED BY THE UNIVERSITY,
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THE INFLUENCE OF MAGNESIUM SULPHATE ON THE MOTOR CELLS OF THE CEREBRAL CORTEX.

BY H. F. HYNDMAN AND W. E. MICHENER.

(Contribution from the Physiological Laboratory of the University of Kansas.)

THE experiments of which the results are here briefly recorded were undertaken for the purpose of ascertaining whether magnesium sulphate paralyzed the motor cells of the cerebral cortex. It was found that 1.5 grams of magnesium sulphate per kilo, when injected in rabbits subcutaneously, produced anæsthesia in about fifty minutes that lasted two hours.

Rabbits were employed in all of the tests and three series of experiments were carried out.

In the first set ether was given, and when anæsthesia had developed the motor areas were exposed, and a definite, well-defined small area, which when stimulated with insulated platinum electrodes with a determined minimal strength of induced current, caused the hind leg of the side opposite to the one stimulated to give a definite contraction. The cortex was then carefully removed and again the minimal strength of current determined that would produce the same extent of contraction as before in the same leg. The animal was then allowed to come from under the influence of ether, and then an anæsthetic dose of magnesium sulphate was injected. The same area on the opposite side was now stimulated with a determined minimal strength of current that would produce the same extent of contraction as was secured with ether. The cortex was then removed and again the minimal strength of current determined.

The experiment was also modified in that the minimal strength of current for contraction was determined after cortex stimulation, and then, when the animal recovered from the ether effect, magnesium sulphate anæsthesia was secured. Again the cortex was stimulated with a minimal strength of induced current.

The results of this set of experiments were that it required exactly the same strength of current to produce the same extent of contractions, both with the cortex intact as well as when the motor cells were removed and the fibers directly stimulated under ether as under magnesium sulphate anæsthesia. In each case the strength of current required for the same contraction was greater when the motor fibers were directly stimulated after the motor cells were removed than when the contractions were secured indirectly by direct stimulation of the motor cells.

The second set of experiments differed from the first set in that the same procedure was carried out under magnesium sulphate anæsthesia alone.

The third set of experiments consisted in determining the strength of current when applied to the central ends of the eighth and seventh cervical dorsal spinal nerves under ether and magnesium sulphate anæsthesia that would reflexly cause contraction of certain muscles of the mouth.

A comparison of all the experiments showed that the same minimal strength of current was required to produce the same extent of contraction under ether as under magnesium sulphate anæsthesia, whether applied directly to the motor fibers, indirectly to the fibers through the motor cortical cells, or when applied to afferent fibers that secured a reflex response; and that a greater strength of current was required when applied directly to the motor fibers than when the impulses reached these through stimulation of the motor cortical cells.

We conclude, therefore, that magnesium sulphate anæsthesia does not paralyze the motor cells of the cerebral cortex in the rabbit.

We take this opportunity to thank Doctor Hyde, under whose supervision these experiments were conducted, for her many kind suggestions.

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A STUDY OF THE RESPIRATORY AND CARDIAC ACTIVITIES AND BLOOD PRESSURE IN THE SKATE FOLLOWING INTRAVENOUS INJECTIONS OF SALT SOLUTIONS, ... *Ida H. Hyde.*

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A STUDY OF THE RESPIRATORY AND CARDIAC ACTIVITIES AND BLOOD PRESSURE IN THE SKATE FOLLOWING INTRAVENOUS INJECTIONS OF SALT SOLUTIONS.

BY IDA H. HYDE.

Plate X, and 49 figures.

(From the Marine Biological Laboratories of Woods Hole and Leland Stanford[1] and the Physiological Laboratory of the University of Kansas.)

THE experiments that are recorded in this article were conducted on the skate, *Raia erinacea* and *Raia binoculata*, during the summers of 1902, 1903, 1906 and 1907.

A host of articles have accumulated since Humboldt first studied the action of salt solutions upon the rhythmical changes in the heart's contractions; but with the progress of physical chemistry new problems and different views presented themselves and left many important questions still unsettled. To aid in solving some of these I undertook the study from a less general standpoint by employing a method and an animal seldom heretofore adopted in the solution of the questions. A few experiments were begun on the fresh-water sturgeon and on the frog in order to compare the results with those obtained with the skate. These, however, will be extended and varied before the results are published.

It was hoped that simultaneous records and comparisons of the three activities might throw some light upon the factors that influence them and indicate whether their nerve centers are alike stimulated by the same ions. At first the object was also to determine whether it was the anion or cathion that stimulated the different centers, and if there were ions that simulated one but proved neutral or inhibitory to the other centers. Moreover, whether valency or solution tension were influential factors, and if the toxicity produced on either the respiratory, cardiac or vasomotor centers by certain salts could be counteracted by definite amounts of other salts that proved antitoxic. Before I had proceeded far, however, I desired, in addition to the solution of some of these questions, to study other physical and chemical effects that were produced in the body by the salts; *e. g.*, osmotic pressure, the products of chemical reactions, such as oxygen, carbon dioxide, hydrogen and hydroxyl ions, and the dosage of the solutions.

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[1] I take this opportunity to express my hearty thanks to the directors for the privilege of working in these institutions and for the courtesies I received there.

I realize that in experiments of this character a host of phenomena may exert their influence and that it is difficult with the data at hand to assign to any special one the cause that produces the particular result. Some of the events which may deserve consideration can, however, be controlled and their influence either accounted for or removed from further consideration. That is especially so in the investigation of the fishes, where the temperature and supply of the water can be controlled and are kept normal and constant throughout the experiment and where the amount of solution injected bears a direct proportion to the weight of the animal, and also where from the method employed mechanical stimulation, either due to the insertion of the cannula or brought about by retaining the fish in a definite position during the experiment, is avoided.

On the other hand, we assume that the addition of an isotonic salt solution to the blood, the chosen amount of which does not cause any change in any of the functions under consideration, will, if hypo- or hyper-tonic, produce various physical and chemical alterations both in the fluids and tissues of the body. Introducing an additional salt into the blood assumes changes in its osmotic pressure and in the contents of the corpuscles, also alterations in the permeability of the walls of the capillaries, corpuscles and other tissue cells. Or the new composition in blood salts may make new combinations with colloids or ferments or proferments, or set free ions that will thus stimulate or inhibit functions by acting directly on cardiac or muscle cells, or indirectly upon special centers. That is, the physiological property of the blood is altered by changing the proportion and character of the electrolytes in it, and this must have its peculiar influence upon the life phenomena of respiration and heart action and blood pressure. To which of these must be ascribed the important changes produced in respiration and cardiac activity and blood pressure is a question with which I shall not for the present concern myself, since in addition to the experiments which I conducted it would be necessary, as I later saw, to carry on extensive physical and chemical investigations for which I lacked the time. I shall content myself, therefore, by simply stating my method and observations, and not attempt theoretical considerations of the underlying causes, trusting that the data obtained from over 200 experiments will aid in the correct interpretation of results secured by other investigators working upon problems related to those that I undertook.

According to Garry[2] and Sumner[3] the percentage of salts in the skate and selachian's blood does not differ from that in sea water. The lowering of the freezing point being —1.8° C. and the osmotic pressure twenty-two atmospheres, the sea water is therefore isotonic with the skate's blood, while Baglioni[3] estimated it isotonic with an m⅝ NaCl or a 2 per cent NaCl plus 2.5 per cent urea. Although the osmotic pressure of the selachian's blood is the same as sea water, its salt content is less, but the lowering of the freezing point is compensated by the urea in the blood.

Employing Welcker's method, I ascertained that a small skate weighing from 550 to 700 grams possessed 25 to 30 grams of blood, or about one-twentieth of the body weight. Harris[3] states that the weight of the blood in the skate is only one-fortieth of the body weight, but he does not describe the method employed for ascertaining his data.

Although there are wide variations in blood pressure, I found that the mean pressure for an average-sized skate was about 20 mm. of mercury.

The photograph on plate X illustrates one of the methods employed for securing records of the respiratory and cardiac action and blood pressure. The skate was placed ventral side up on an inclined board, partly submerged in water, and held in place by fish netting; a constant stream of fresh sea water of a definite volume, velocity, and temperature entered the mouth through a forked glass tube covered with rubber tubing.

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[2] Garry, W. E. Biological Bulletin, 1905, vol. VIII, No. 4, p. 257.

[3] Sumner, F. B. Bulletin Bureau of Fisheries, 1906, p. 596. Baglioni. Zentralblatt für Physiologie, 1905, vol. XIX, p. 12. Harris, D. F. Journal of Physiology, 1903, vol. XXX, Nos. 3 and 4, p. 319.

As soon as the water enters the mouth and flows out of the gill slits over the body, thus keeping the skate practically submerged, and the netting comes in contact with the body, the fish is perfectly quiet and remains so for hours, apparently contented and comfortable. A cannula, filled with 20 per cent glucose or glucose and 1 per cent ammonium oxalate, is inserted in one of the side branches of the aorta and joined to a delicate mercury manometer placed quite on a level with the blood vessels. To the open end of the manometer is attached a Hürthle manometer, which records the heart action, while the pressure is read off directly from the manometer.

By means of a silk loop one of the gill arches is attached to a light lever which records the respiratory movements. In control experiments the tip of the ventricle was exposed and by means of a silk loop joined to a light lever, so that in addition to the above records, separate ones were obtained of the rate and force of the heart's activity.

The salts employed in the experiments were all chemically pure, either from Kahlbaum or specially prepared in the laboratory, and they were all standardized. The water employed in making up the solutions was twice distilled in glass.

To avoid mechanical stimulation a cannula, to which was connected a rubber tube, was inserted either in the median or lateral caudal vein and tied in place. Subsequently 4 cc. of the solution per kilo weight of fish was slowly pressed from a graduated glass tube into the cannula by means of a rubber bulb attached to its upper end.

During the inspiratory phase the mouth and spiracles are opened, the floor of the mouth is lowered, the gill clefts or external branchial apertures are closed, and water enters the mouth and spiracles. In the expiratory phase the mouth and spiracles close, the floor of the mouth returns to its normal position or is elevated and the gill clefts open to allow the water to escape. Occasionally a peculiar spouting takes place during which water is thrown from the mouth and spiracles. This is observed in the aquarium also and may be due to irritation, touch, stimulation of the mucous lining of the mouth by slime particles or vitiated water.

I first investigated the effect of different concentrations of the same solution, seeking the weakest solution that produced any change in the three functions under consideration; also, which concentration proved toxic, and whether the injurious dose could be modified or antagonized by a definite dose of another salt.

Observations were made and curves secured before, during and after the injection of the salt solutions. From one to five minutes after the injection a change in one or more of the functions under consideration usually occurred, and this was followed by a second change that lasted from five to twenty minutes, before the records again assumed their normal character. The first effect may be the reaction of the salt upon the constituents of the blood and indirectly upon muscle and nerve cells; the second is due to osmotic pressure changes. That injections of hypertonic salt solutions in the blood of the dog increases the osmotic pressure, which may become normal within twenty minutes, was proved by Magnus.[4] Moreover, those salts that set free O, CO_2, H, or OH ions, in their reactions, exert their influence more often through these ions, and effect results that differ from those produced by salts having the same cations, but do not react with the same resulting ion products; *e. g.*, NaCl is different in its effects from Na_2CO_3, probably because of the OH ions set free by the Na_2CO_3 dissociation.

It is possible that the blood pressure, respiratory and cardiac activities depend upon the number of molecules and ions in the blood, and upon the dissociation tension of the salts. The prepotent anions or cations may stimulate or inhibit enzyme action, and thus aid in producing the inner stimulus that affects alike the force of cardiac and respiratory activity and directly or indirectly the blood pressure.

A careful study of very many experiments with the same salts was made, the average results summed up, and the most typical of a series of experiments put in tabular form. Thus table II gives a survey of the different series of experiments and is a summary of all the experiments conducted on the skate with NaCl solutions. It shows that m/32, m/16, m/8, NaCl solutions produce as a rule practically no change in the heart or respiratory activity or blood pressure. An m⅝ NaCl solution (see curve 1) increases the force and blood pressure but leaves the rate of the heart and respiration unaltered.

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[4] Magnus. Archiv für Experimentelle Pathologie, 1900, vol. 44, p. 99,

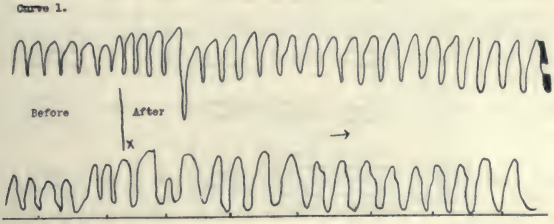
An m/1 solution (curve 2) causes a rise in blood pressure and force of heart's rhythm at once, which usually continues for about twenty minutes. But the force and rate of respiration is either unchanged for one to two minutes and then decreases; or may, as does the heart rate, first decrease and then return to normal.

Following the injection of a 2m NaCl solution (curves 3 and 4) the blood pressure increased for about five minutes, then became normal. The rate and force of the heart and respiratory movements decreased for one to twenty-five minutes; but in many cases the force of the heart's activity first decreased for one to two minutes and then increased, or increased as the blood pressure rose. In every instance the systole and inspiratory phases were prolonged above normal with a 2m NaCl solution.

A *résumé* of the NaCl experiments shows that injections of 4 cc. per kilo fish of m/64 to m/8 solutions are as a rule practically indifferent; m⅝ stimulates the force of heart and respiratory activity and raises blood pressure for from one to five minutes, but is usually indifferent to rate; m/1 increases the force of the heart's action and also blood pressure, but the rate and force of respiratory activity differs in that they may for one minute remain normal, then decrease; or may, as does the heart rate, decrease for one to three minutes before resuming again the normal activity; 2m decreases rate and force of heart and respiration, but the heart's force is often increased after one to two minutes' decreased action. The blood pressure is raised during the first one to five minutes, then falls.

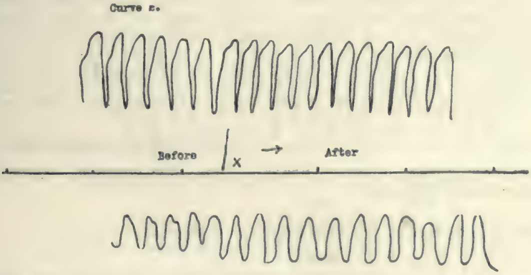
It might be concluded that the blood salts can be slightly increased by 4 cc. per kilo m/64 to m/8 without stimulating or inhibiting either of the three functions that are considered, and that equilibrium of the osmotic pressure is rapidly established. On the other hand, m⅝ stimulates the force of both heart and respiration. I infer that its effect is directly upon the nerve centers for one to five minutes, before the attraction of water to the blood establishes equilibrium. An increase to m/1 has a stimulating effect only upon the force of the cardiac center, thereby increasing also the blood pressure, but strangely enough does not affect the respiratory center in the same direction but rather depresses its force and rate, as well as the rate of the heart's activity. But a 2m solution has again a like depressing influence upon both force and rate of respiratory and cardiac rhythm and at first causes a rise in blood pressure.

CURVE 1. Following an injection of m⅝ NaCl. Lever attached to heart and gill arch.



Upper, respiration. Lower, cardiac curve. Injection at X. Force of heart and respiratory action increased, but not rate.

CURVE 2. After NaCl. Lever attached to heart and gill arch. Normal before X.



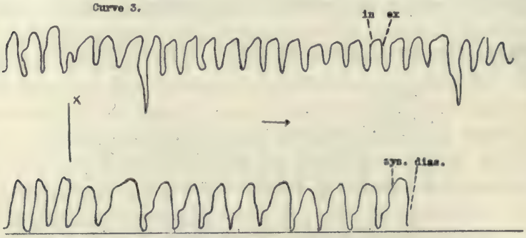
Upper, respiration. Lower, cardiac curve. Heart and respiratory rate unchanged; force of former increased but of latter unchanged or even less. Time, five seconds.

Data of the mean results in respiration, heart action and blood pressure of many experiments on the skate. Different concentrations of NaCl were intravenously injected in the proportion of 4 cc. per kilo fish:

TABLE I. Effect of NaCl solutions.

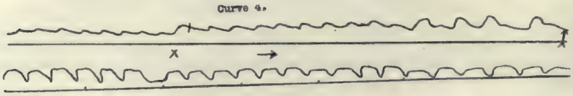
Salt amt.	Mol.	Heart rate.	Heart force.	Respiratory rate.	Respiratory force.	Blood pressure.		Time of change.	Curves.
						Normal.	Change		
NaCl 2 cc.	m/32	Neutral.	Neutral.	Neutral.	Neutral.	24	24		
NaCl 2 cc.	m/16	Neutral.	Neutral.	Neutral.	Neutral.	20	20		
NaCl 2 cc.	m/8	Neutral.	Neutral.	Neutral.	Neutral.	14	14		
NaCl 2 cc.	m⅝	Neutral.	Increased.	Neutral.	Increased.	26	28	First 1-5 minutes.	1
NaCl 2 cc.	m/1	Fell 1-3 minutes, then normal.	Increased at once.	Normal or less.	Normal or less.	17	20	During 20 minutes.	2
NaCl 2 cc.	2m	Fell 36-30; systole prolonged.	First 1-2 minutes rose, then decreased.	First 5 min. fell, inspiration prolonged.	Decreased.	20	23	First 5 minutes.	3, 4

CURVE 3. After 2m NaCl. Heart directly attached to lever.



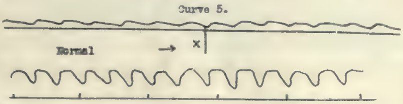
Upper, respiration. Lower, heart. Time, five seconds. Systole and inspiration much prolonged.

CURVE 4. 2m NaCl. Hürthle mercury manometer.



Normal, 10:35 A. M.	10:40 A. M.	10:45 A. M.
Heart rate, 36.	Heart rate, force slightly increased.	Heart rate, 30, force increased.
Respiration rate, 36.	Respiration rate 27, force slightly decreased.	Respiration rate 36, force less.
Pressure, 20.	Pressure, 23.	Pressure, 23.

Curve 5. M/32 KCl. Heart and blood pressure were obtained with Hürthle manometer. For respiratory records the lever was attached to the gill arch.

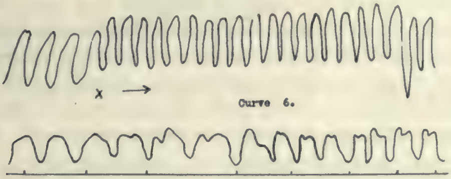


The upper curve heart, and from abscissa to heart blood-pressure record.

Below the latter respiratory curves, and the time in five seconds.

Blood pressure remained unchanged, respiratory rate decreased, force unaltered, expiratory phase prolonged. Heart rate from 24 to 22, prolonged diastole and force unchanged.

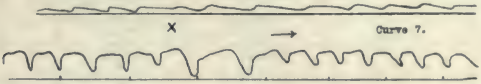
Curve 6. M/8 KCl. Lever attached to the tip of the ventricle and gill arch.



Upper, respiratory curve. Lower, heart. Time in five seconds.

The first part of the upper curve of respiration, taken before injection, registered 36; immediately after, force slightly less, but the rate increased to 42, and in ten minutes was normal again. The first part of the lower heart curve before injecting was 34 per minute. For about twenty minutes it was less (27), with prolonged diastole, then gradually increasing during fifteen minutes to normal. Force was unchanged.

Curve 7. Effect of m/8 KCl.

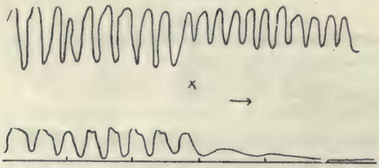


Upper, heart and pressure recorded with Hürthle mercury manometer. Lower, respiratory records from lever attached to a gill arch.

Pressure before injecting m/8 KCl 20 mm.; after injecting for two minutes 22 mm., then normal. After injecting the solution, the respiration for about twenty seconds decreased in rate with prolonged inspiration, then for about one minute increased, and in fifteen minutes was normal. Force was unchanged for twenty to sixty seconds, heart rate decreased with prolonged diastole, then in five minutes normal; force unchanged.

Curve 8. M⅝ KCl. Curves secured with heart and respiratory levers.

Curve 8.

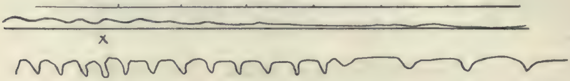


Upper, respiration. Lower, heart curve.

Within one to two minutes after the m⅝ KCl was injected, the heart action ceased. Respiratory force decreased, rate increased, and stopped in twelve minutes.

Curve 9. m⅝ KCl. Curves secured with lever and Hürthle manometer.

Curve 9.



The upper are cardiac, the lower are respiratory records. Time, five seconds.

Within one minute blood pressure and heart action were zero. Respiratory rhythm decreased and in twenty minutes stopped.

Table II. Mean results in respiration, heart action and blood pressure following injection of different concentrations of KCl solutions.

Salt mol. 4 cc. per kilo.	Heart rate.	Time.	Heart force.	Respiratory rate.	Time.	Respiratory force.	Blood pressure.		Curves.
							Normal.	Change	
KCl m/100	Neutral.		Unchanged.	Unchanged.		Unchanged.	18	18	
KCl m/32	Slower.	20-60 sec.	Unchanged.	Increase, then less, or less at once.	20-60 sec.	Decreased or unchanged.	18 20	18 20	5
KCl m/8	Decreased.	20-60 sec.	Unchanged.	Decreased.	At once.	Unchanged.	20 20	18, 22, then 20	6 7
KCl m⅝	Decreased, then ceased.	5 sec.	Increased for 30 sec. then less.	Increased, stopped or decreased.	5 sec.; 7 min.	Decreased.	19 or 20	22, 1 min. 0, in 8 min.	8 9

The influence of KCl injections are summarized in table II, which represents the mean results of many experiments of the different series of KCl solutions. Curve 5 is a typical curve secured after injecting the usual amount of an m/32 KCl solution. From the table and the curve it is observed that an m/32

KCl solution produces a first effect of from twenty seconds to one minute upon the heart and respiratory activities. More often during this time the heart rate is slower, due to prolonged diastole, and the force remains unchanged. The inspiratory phase is, however, lessened while the expiratory is relatively prolonged.

Curves 6 and 7 represent records obtained with different methods after injecting an m/8 KCl solution. Although many other records were made these were chosen because they represent the more general type. There were exceptions in every case, but those variations were accounted for either because of the morbid condition of the skate, because it had been in the aquarium several days, or had been under observation for several hours and was fatigued or more or less irritable. After the solution was injected for from twenty to sixty seconds the heart activity greatly decreased and diastole was much prolonged. Occasionally the action increased above the normal rate for one to two minutes, and in ten to fifteen minutes was normal. The force remained unchanged. The respiratory rate as a rule decreased for fifteen to thirty seconds, with prolonged inspiratory phase, then either suddenly increased above normal or gradually returned to the normal rhythm. The force was usually unchanged. The blood pressure either fell or increased slightly, about 2 mm. mercury, for from one to two minutes.

Following the injection of m⅝ KCl, pressure fell either very suddenly to zero or in rapid leaps from 20 to 16 in one minute and zero in two minutes, or often 19 to 22 in one minute then zero within three minutes. The heart decreased in rate; *e. g.*, from 30 to 18, with increased force in one and zero in two minutes. Respiration slowed from 39 to 30 in five seconds to 18 and very shallow and often irregular and spasmodic in ten minutes, or rapid, 46 to 60, in five seconds, and gradually to zero in seven minutes, but in some cases continued active as long as twenty minutes after the heart had ceased contracting.

A *résumé* of the effects of KCl solutions brings to light that diastole and inspiratory phases are prolonged above normal in the different strengths of solution. Blood pressure falls in all but the most dilute solutions. The force of the heart and respiratory activity is practically unchanged in all but the toxic strength, m⅝, after which it decreases. The rate of the heart's contractions as a rule is at first decreased in all strengths but the m/100; m$\frac{5}{8}$ is toxic to heart and respiratory activity, though usually the respiratory rhythm continues for five to twenty minutes after the heart has ceased.

A summary of some experiments that were undertaken to study what salts counteracted the toxic influence of KCl solutions is shown in table II*b*, and curves 10, 11, 12 and 13 illustrate a few of the experiments.

Curve 10 records the antitoxic effect of an m$\frac{5}{8}$ NaCl solution. The rate of the heart's action was 36, that of the respiratory 26. At 10:05 m$\frac{5}{8}$ KCl was injected; within a few seconds the heart action became irregular and respiration rapid, then irregular, with prolonged expiratory phases. Blood pressure fell. At 10:15, an injection of m$\frac{5}{8}$ NaCl was followed in a few seconds by regular and strong cardiac and respiratory contractions, which in ten minutes were quite normal, but the force of the heart-beat was stronger. In other experiments the toxic effect of an m$\frac{3}{8}$ KCl was quickly counteracted by an m/8 NaCl solution.

Curve 11 shows the favorable influence of $CaCl_2$ with or preceding a KCl solution; m/4 KCl following m/4 KCl+m/32 $CaCl_2$ shows a decrease in force of heart and respiratory activity, and a toxic m$\frac{5}{8}$ KCl following a mixture of m$\frac{5}{8}$ KCl+m/32 $CaCl_2$ shows, in addition to a decrease in rate, a marked decrease in force, but in twenty minutes the heart and respiratory rhythm is almost normal. The $CaCl_2$ evidently proved antitoxic, and with KCl enhances the force of both respiratory and cardiac action.

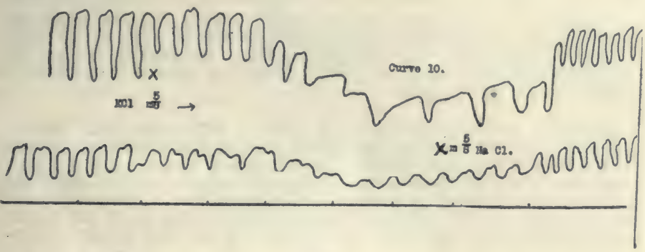
Curve 12 also shows that a dose of m/4 $CaCl_2$ that preceded an m$\frac{5}{8}$ KCl and m/1 KCl counteracted their toxic effects.

Curve 13: After $CaCl_2$ m$\frac{4}{8}$, blood pressure stood at 14 mm., heart action at 24, respiratory action at 36. When m$\frac{5}{8}$ KCl was injected, pressure fell to 2 mm, heart to four contractions and respiration increased to 42. At the end of two minutes pressure was again 14, heart and respiratory rate had increased, though shallow. At the end of five minutes, pressure and action of heart and respiration were quite normal, but respiratory rate more rapid. This shows that when stronger solutions of Ca are injected, and the blood is in excess of the normal, it counteracts the toxic effect of m$\frac{5}{8}$ solution of KCl quicker and the toxicity is less marked on respiratory than heart action. In some experiments the toxic effect of KCl m$\frac{5}{8}$ was overcome if $CaCl_2$ was injected soon after the KCl solution.

TABLE II*b*. Salts that counteracted the toxic effect of m$\frac{5}{8}$ KCl.

Salt amt.	Mol.	Heart.	Respiratory.	Blood pressure.	Antitoxic.	Mol.	Heart.	Respiratory.	Blood pressure.	Curves.
4 cc. KCl. per kilo.	m$\frac{5}{8}$	Irregular, then spasmodic.	Rapid, then spasmodic.	Pressure fell.	$NaCl_2$ cc. followed m$\frac{5}{8}$ KCl.	m$\frac{5}{8}$	Regular in two minutes.	Regular in two minutes.	Rose.	10
KCl	m/4 subsequent.	Rate unchanged, force less.	Rate increased, force less.		$CaCl_2$ + KCl. Preceded.	m/32 m/4	Rate unchanged, force increased.	Rate less, force increased.		11
KCl	m$\frac{5}{8}$ subsequent.	Rate and force less.	Rate and force less.		CaCl + KCl. Preceded.	m/32 m$\frac{5}{8}$	Rate and force increased.	Rate and force increased.		11
KCl	m$\frac{5}{8}$	Slight increase in rate and force	Rate slight increased, force less.		$CaCl_2$.	m/4	Stimulant force and rate antitoxic.	Stimulant force and rate antitoxic.	Rose.	12
KCl	m/1	Unchanged.			Preceded.					
KCl	m$\frac{5}{8}$ subsequent.	Almost stopped; in five minutes quite normal.	Rate increased, force fell, then normal.	Fell.	$CaCl_2$. Preceded. m$\frac{5}{8}$ KCl.	m$\frac{1}{4}$	24	36	Normal.	13

CURVE 10. Toxic action of KCl m$\frac{5}{8}$ counteracted by NaCl m$\frac{5}{8}$. Levers attached to ventricle and gill arch.



Time, five seconds. Upper, respiration. Lower, cardiac curves.[5]

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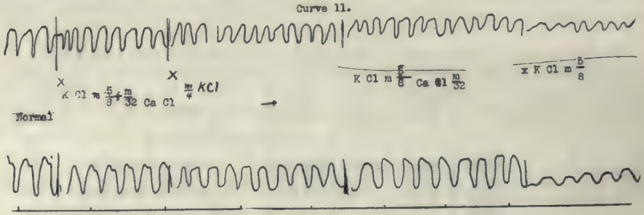
[5] Within a few seconds after injecting m$\frac{5}{8}$ at X, the heart action became irregular and spasmodic in long diastole. In twenty-five seconds the greatly increased respiratory movements assumed prolonged expiratory spasms and a few seconds following m$\frac{5}{8}$ NaCl injection both respiratory and cardiac action became more regular again. m$\frac{5}{8}$ NaCl proved antitoxic for the toxic dose of m$\frac{5}{8}$ KCl.

CURVE 11. Toxic effect of KCl m⅝ counteracted by $CaCl_2$ m/32 for the upper curve. For lower curve, the lever was attached to the ventricle, and to the gill arch for upper.

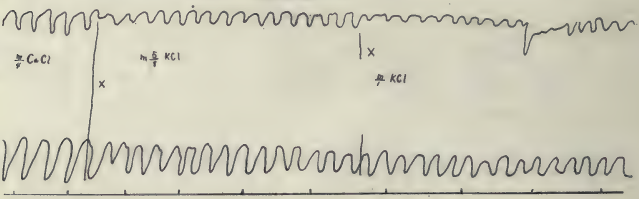
Curve 11.



Showing the antitoxic and stimulating action of $CaCl_2$ 2 cc. m/4 KCl+ m/32 $CaCl_2$. Rate of heart contractions increased. KCl m/4 decreased the force of heart and respiration, while rate of respiration increased. The difference between the effect of m⅝ KCl and KCl m⅝ plus $CaCl_2$ m/32 demonstrates that $CaCl_2$ increases force of heart and respiration.

CURVE 12. Toxic effect of KCl m⅝ or m/1 counteracted by a previous dose of $CaCl_2$ m/4. For lower record the lever was attached to the ventricle, and to the gill arch for the upper curve.

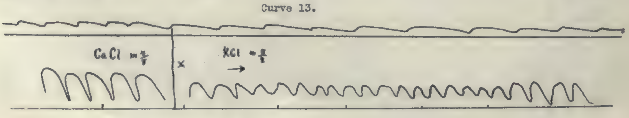
Curve 12.



Following 8 cc. of gradually increasing to m/4 doses of $CaCl_2$ the heart became distended and contracted more forcibly, due to the intracardiac pressure; m⅝ KCl injected increased the rate of cardiac and respiratory activity and an m/1 KCl injected ten minutes later failed to produce its usual toxic effect.

CURVE 13. KCl m⅝ following m4⁄8 $CaCl_2$. After m4⁄8 $CaCl_2$ was injected the pressure stood 14 mm., heart rate 24 and respiratory 36. At 3:50 P. M. KCl m⅝ was injected. In one minute pressure fell to 2 mm., heart rate to 4 and respiratory rate increased to 42. At the end of two minutes pressure stood 14, heart force increased rate 8, respiratory rate 48, force less. At the end of five minutes pressure and heart action were quite normal while respiration was abnormal in rate but normal in force.

Curve 13.



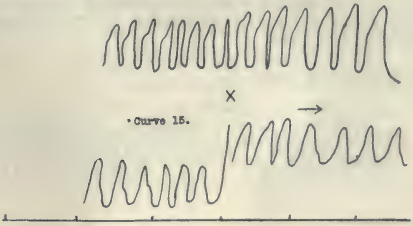
Upper curve, heart and pressure from abscissa. Lower curves, respiration. Time, five seconds. Records with Hürthle and lever manometer.

The results of the experiments with $CaCl_2$ are briefly tabulated in table III and partly shown in curves. It was observed that after an injection of the usual amount of m/32 $CaCl_2$ solution (curves 15, 16), the blood pressure remained unchanged. Respiratory activity was usually increased for one to three minutes, and the cardiac contractions continued unchanged or did so after about one minute of decreased rate and increased force. Following an injection of an m/8 $CaCl_2$ solution, the rate of cardiac and respiratory activity is usually decreased and the force of both increased. The blood pressure rises for about one minute. Often systole and inspiratory phases predominate, and furthermore, the solution proved antitoxic to many toxic salt solutions. The effect of an m$\frac{5}{8}$ $CaCl_2$ was first a decrease in rate of cardiac and respiratory activity, often irregular, with prolonged systole and inspiratory phases. The force of both activities was usually increased, as was also the blood pressure, for from one to three minutes. If the force of the heart-beat was not increased the blood pressure did not rise above normal.

Table III. Mean results in respiration, heart action and blood pressure, following injections of different concentrations of $CaCl_2$ solutions.

Salt mol.	Heart rate.	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.		Curves.
							Normal.	Change	
$CaCl_2$ m/32	Unchanged or decreased.	Unchanged or increased.	1 min.	Unchanged or increased.	Unchanged or increased.	3 min.	20	20	15, 16
$CaCl_2$ m/8	Decreased or unchanged.	Increased or unchanged.	1–3 min.	Unchanged or decreased.	Unchanged or increased.	1–3 min.	17	18	17, 18
$CaCl_2$ m$\frac{5}{8}$	Decreased or irregular.	Increased.	1–3 min.	Decreased or irregular.	Increased.	1–3 min.	22	24, 22	19, 20

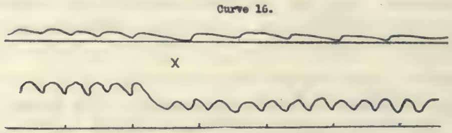
Curve 15. Following an injection of m/32 $CaCl_2$.



Rate less and force of heart unchanged; rate of respiratory activity decreased for one minute, then normal, force increased.

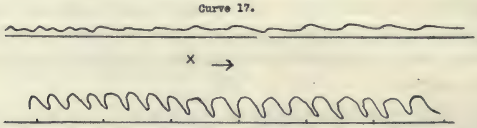
The upper respiratory and the lower cardiac records were secured with levers directly attached to gill arch and apex of heart.

CURVE 16. After m/32 $CaCl_2$.



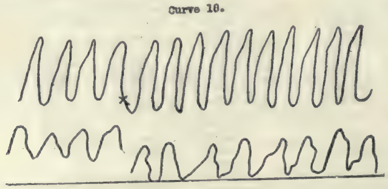
The upper curve, Hürthle manometer heart record. Lower curve, gill-arch lever records of respiratory activity. Rate of heart decreased, force unchanged. Respiratory activity and pressure unchanged.

CURVE 17. Effect of m/8 $CaCl_2$.



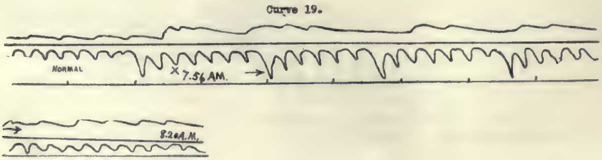
The upper curve is a record of the cardiac and blood-pressure changes secured with a Hürthle manometer. The lower respiratory is a gill-arch lever record. Rate decreased, force increased for both activities and blood pressure showed slight rise for a minute or two.

CURVE 18. Effect of m/8 $CaCl_2$.



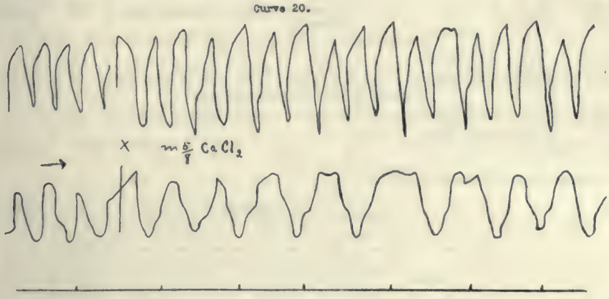
Upper, cardiac record secured with lever attached to the heart. Lower, gill-arch record. Respiratory rate unchanged, force increased. Cardiac rate decreased, force increased.

CURVE 19. Effect of m⅝ $CaCl_2$.



Hürthle cardiac records above, gill-arch lever records below. Time, five seconds. Cardiac and respiratory rate decreased, force and blood pressure increased for about three minutes, then quite normal for about thirty minutes. First effect often irregular and spasmodic, especially for cardiac rhythm.

CURVE 20. Effect of m⅝ $CaCl_2$.



Upper curve respiratory, lower cardiac. Levers directly attached to heart and gill arch. Cardiac and respiratory rates first decreased, force increased; irregular prolonged diastole and inspiratory phases.

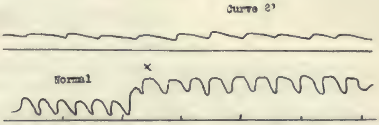
The results following injections of $MgSO_4$ solutions are summarized in table IV, and illustrated in the curves. It was observed that an m/64 or m/8 $MgSO_4$ had a more depressing influence on respiration than on cardiac activity. The rate was either unchanged or less, but force and blood pressure usually slightly greater for cardiac, while rate and force of respiratory activity were generally decreased.

An m⅝ or m/1 solution produces for about two minutes an increase in blood pressure followed by a decrease. Respiratory and cardiac rate and force both decrease, but occasionally the force of the heart's activity is first increased. Sensory reflexes are all reduced. With every strength of the solution the force and rate of the respiratory rhythm and the cardiac rate were decreased, but blood pressure and cardiac force were increased or decreased after a previous increase. With strong solutions, *e. g.*, m/1, diastole and expiratory phases predominated and the activities may become irregular, but an m/8 $CaCl_2$ overcomes the toxic effect and increases the force of the respiratory phase and blood pressure.

TABLE IV. Mean results in cardiac and respiratory activity and blood pressure following injection of different concentrations of $MgSO_4$.

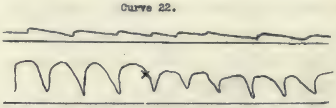
Salt mol.	Heart rate.	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.	Pressure change.	Curves.
$MgSO_4$ m/64	Less or unchanged.	Unchanged or increased.	15 min.	Less or unchanged.	Less.	15 min.	20	21 20	21
$MgSO_4$ m/8	Less or unchanged.	Increased or unchanged.	5 min.	Less or unchanged.	Less.	5 min.	18	19 18	22
m5/8 or m/1	Less or unchanged.	Decreased after rise.	Rise 2 m.	Less.	Less.	3 min.	22	23 21	23

CURVE 21. Effect of $MgSO_4$ m/64.



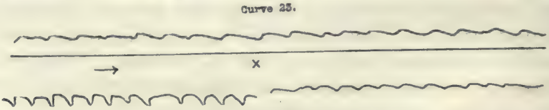
Upper curves, cardiac and pressure with Hürthle. Lower, respiratory gill-arch lever. Time, five seconds. At x, injection. Cardiac rate less, force and blood pressure slightly greater; respiratory rate less, force unchanged.

CURVE 22. Effect of $MgSO_4$ m/8.



Upper curve, cardiac and blood pressure shows decrease in cardiac rate, slight increase in force and blood pressure, for two minutes. Lower, respiratory gill-arch lever curve; decrease in force, not in rate.

CURVE 23. Effect of $MgSO_4$ m⅝.



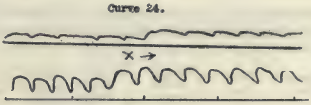
Upper curves, cardiac and blood pressure; rate unchanged, force and blood pressure slightly increase for two minutes, then decrease. Lower, respiratory curve, decrease in rate and force.

The effects of Na_2CO_3 injections are tabulated in table V. It was observed that Na_2CO_3 solutions are most effective in strengthening the force of the cardiac rhythm and thus raising the blood pressure. They do not stimulate respiratory activity except in strong doses, when they may increase the force. Its pronounced influence upon the heart may be due to OH ions that are set free by the dissociation.

TABLE V. *Résumé* of Na_2CO_3 injections upon cardiac and respiratory activity and blood pressure.

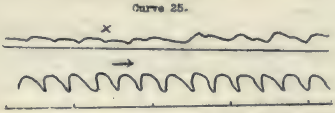
Salt.	Heart rate.	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.	Pressure changes.	Curves.
Na_2CO_3 m/32	Unchanged.	Increased.	15 min.	Unchanged.	Unchanged.		22	24	24
m/8	Unchanged or less.	Increased.	15 min.	Unchanged.	Unchanged.		20	23	25
m⅝	Unchanged or less.	Increased.	2 min.	Unchanged or decreased.	Increased.		26	28	26

CURVE 24. Effect of Na_2CO_3 m/32.



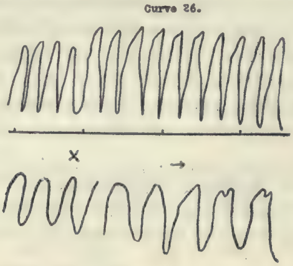
Upper curves, cardiac and blood pressure with Hürthle. Rate unchanged, force and blood pressure increased. Lower, respiratory; force and rate unchanged. Time, five seconds.

CURVE 25. Na_2CO_3 m/8.



Upper curves, cardiac and blood pressure. Rate decreased, force greatly increased, pressure rose. Lower curve, respiratory; force and rate unchanged. Time, five seconds.

CURVE 26. Na_2CO_3 m/2.



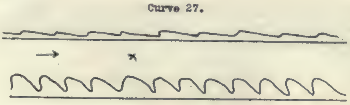
Upper, respiratory gill-arch lever records. Increased force, decreased rate. Lower, cardiac lever directly attached to heart. Increased force, decreased rate. Time, five seconds.

Na_2HPO_4 solutions are not so stimulating to cardiac rhythm as are Na_2CO_3 solutions. This is shown in table VI. Moreover, for the same strength they are more toxic. The solutions act like Na_2CO_3 chiefly upon the force of the cardiac action and are indifferent in weak solutions on respiratory movements.

TABLE VI. A summary of experiments of intravenous injections of Na_2HPO_4 relating to cardiac and respiratory activity and blood pressure.

Mol. sol.	Heart rate.	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.	Change.	Curves.
Na_2HPO_4 m/64	Less or unchanged.	Increased or unchanged.	5 min.	Unchanged.	Decreased.	5 min.	23	24	27
m/8	Less or unchanged.	Increased or unchanged.	5 min.	Increased or unchanged.	Decreased.	5 min.	24	22	28
m/4	Less, then rapid or stopped.	Less.	5 min.	Less, then rapid.	Decreased.	3 min.	23	18	29

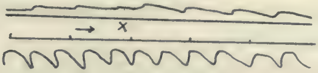
CURVE 27. Effect of Na_2HPO_4 m/64.



Upper, cardiac and blood-pressure Hürthle manometer curves; show force of heart action and blood pressure; slight increase, rate decrease. Lower, respiratory rhythm unaltered. Time, 5 seconds.

Curve 28. Effect of Na_2HPO_4 m/8.

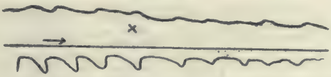
Curve 28.



Upper, cardiac and blood-pressure Hürthle manometer curves. Rate little less, force slight increase. Lower, respiratory record; shows rate unchanged, force decreased, pressure decreased.

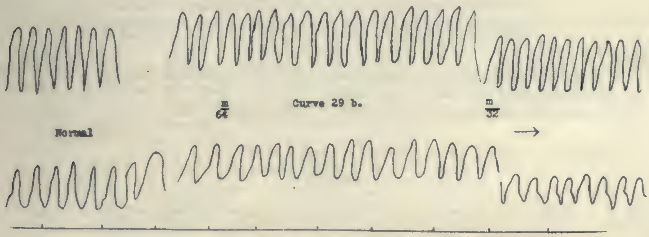
Curve 29. Na_2HPO_4 m/4.

Curve 29.



Upper, cardiac and blood-pressure Hürthle curves; show fall in blood pressure and for three minutes almost cessation of cardiac action. Lower, respiratory, force much decreased.

Curve 29*b*. Effect of gradually increasing strength of Na_2HPO_4 solutions.



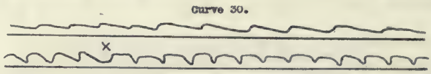
Upper, respiratory gill-arch lever curves show that with increasing strengths from m/64, m/32, m/8, m/4, solutions that the rate increased and force decreased from the normal and that this solution is more favorable to respiration as stimulating rate. Lower, cardiac apex lever curve shows that the rate remained practically unchanged except in m/4, when it became rapid and force decreased gradually from the normal.

The influence of NaOH solutions is briefly tabulated in table VII. It is demonstrated that it acts, augmenting in all concentrations, on the force of the heart-beat and has not the same but rather a depressing effect on the respiratory center. The OH ions here, as in the Na_2CO_3, are the stimulating factors, but act more powerfully than in Na_2CO_3 solutions. The respiratory force decreases with increased strength of the solution, while the blood pressure rises in all concentrations employed, showing that increase in blood pressure is not necessarily associated with rise of respiratory activity but rather with force of heart-beat.

TABLE VII Showing the effect of NaOH solutions upon respiratory, cardiac and blood-pressure changes.

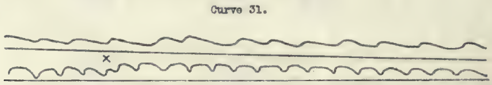
Salt mol.	Heart rate	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Pressure.	Pressure change	Curves.
NaOH m/64	Unchanged or less.	Increased.	5 min.	Unchanged.	Unchanged.	25	26	30
m/32	Unchanged or less.	Much increased.	15 min.	Decreased or unchanged.	Decreased or unchanged.	24	29	31
m/8	Unchanged.	Increased.	10 min.	Increased.	Decreased.	24	27	32
m/4	Less or unchanged.	Increased.	10 min.	Unchanged or increased.	Decreased.	26	29	33

CURVE 30. Effect of m/64 NaOH injections.



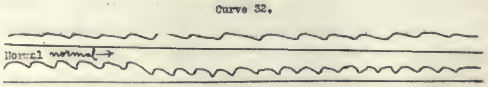
Upper, Hürthle curves of cardiac and blood-pressure changes; decrease in rate, increase in force and blood pressure for two minutes. Lower, gill-arch lever curves of respiratory changes unaltered.

CURVE 31. Effect of m/32 NaOH solutions.



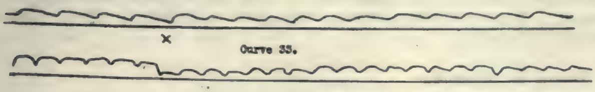
Upper, Hürthle curves of cardiac and blood-pressure changes show a first effect of two minutes of greatly increased force and slight decrease in rate of cardiac rhythm. The blood pressure increased for two minutes, respiratory rhythm decreased very little if at all.

CURVE 32. Effect of m/8 NaOH solutions.



Upper, Hürthle curves of cardiac and blood-pressure changes show increased blood pressure and rhythm. Lower, respiratory curves, increased rate but decreased force.

CURVE 33. Effect of m/4 NaOH solutions.



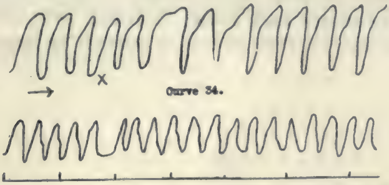
Upper curves, blood pressure and force of cardiac rhythm increased. Lower, respiratory activity decreased in force, rate increased.

From the series of experiments with different concentrations of urea solutions the conclusion is drawn that injection of urea solutions of high concentrations, 2m to 4m, increases force of respiratory and cardiac activity mainly. The rate is practically unchanged, and weaker solutions are quite indifferent on blood pressure, cardiac and respiratory activity. It has been found by Schröder[6] that selachian's blood normally contains 2.6 per cent of urea, and Baglioni[7] found that the selachian's heart beats longer in urea than in NaCl. According to Loeb it is due to the OH ions which are present when the dissociation of the urea occurs. A weak solution of m/20 of Na_2CO_3, to which a 2m urea solution has been added, greatly increased the force of cardiac action and blood pressure.

TABLE VIII. Effect of urea solutions.

Salt mol.	Heart rate.	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.	Pressure changes.	Curves.
Urea, m/50	Unchanged.	Unchanged.	15 min.	Unaltered.	Unchanged.	15 min.	20	20	
m/1	Unaltered.	Unaltered.	15 min.	Unaltered or less.	Unaltered or increase.	1 min.	21	21	34
2m.	Slight rise.	Slight increase.	2 min.	Unchanged.	Unaltered.	15 min.	20	20	35
4m.	Unchanged.	Increase.		Unchanged.	Increase.		22	21	36

CURVE 34. Urea m/1.



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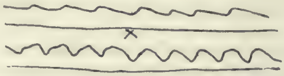
6. Schröder. V. Zeitschrift für Physiologische Chemie, XIV, S. 596.
7. Baglioni. Zentralblatt für Physiologie, 1905, XXX, No. 12.

Upper, respiratory curve, with lever attached to gill arch, shows first decrease in rate for about one minute, then rate normal, force slightly increased. Lower, cardiac curve, with lever attached to apex. Cardiac activity unaltered.

CURVE 35. Urea 2m.

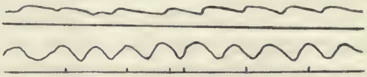
Curve 35.



Upper, Hürthle cardiac record shows little increase in force and rate. Lower, respiratory rate and force unaltered.

CURVE 36. Urea 4m.

Curve 36.



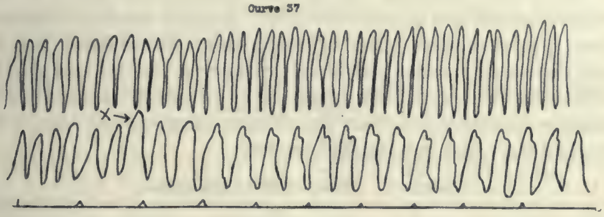
Upper, Hürthle cardiac curve; increased in force and pressure, rate unchanged. Lower, respiratory curve; force slight rise, rate unchanged.

The results obtained with standardized HCl solutions are tabulated in table IX. The weaker solutions, ranging from m/100 to m/64, increase for the first minute or two the force of the cardiac and respiratory and blood-pressure changes, and decrease or act indifferently on the rate of respiratory and cardiac activity. A stronger solution, m/32, for the first minute or two decreases the rate but usually increases the force of both the respiratory and heart action, and the blood pressure usually rises for the first minute; m/8 is toxic, but the respiratory rhythm continues several minutes after the heart ceases, or if it continues it is rapid and faint and the respiratory movements are continued with less force and rate. It is supposed that the stimulating action is due to the H ions. In all concentrations between m/100 and m/16 there is an initial increase in pressure and force, followed by a decrease in all activities before a return to either normal or less.

TABLE IX. Effect of HCl solutions.

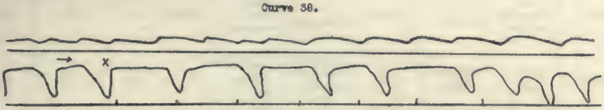
Salt mol.	Heart rate.	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.	Pressure changes.	Curves.
HCl m/64	Decreased.	Increased.	2 min.	Unchanged.	Increased or unchanged.	2 min.	19	20	37
m/32	Decreased.	Increased.	1 min.	Decreased.	Unchanged or increased.	1 min.	24	26	38
m/8	Rapid.	Weak.	1 min., then decreased.	Increased.	Unchanged or increased.	1 min., then decreased	21	10 0	39

CURVE 37. Effect of m/64 HCl on cardiac and respiratory activity and blood pressure.



Upper, gill-arch lever respiratory curve shows for two minutes increased force, rate unchanged. Lower, apex lever cardiac curve for two minutes increased force, decreased rate.

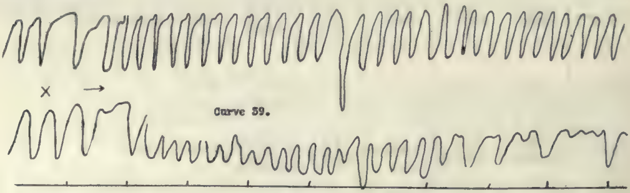
CURVE 38. m/32 HCl injection.



Upper, cardiac Hürthle manometer curve and blood pressure shows decreased rate and increased force and rise of blood pressure for one minute.

Lower, gill-arch lever record of respiratory activity shows rate less, force unchanged for one minute.

CURVE 39. Effect of m/8 HCl on cardiac, respiratory and blood pressure changes.



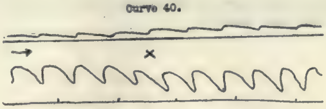
Upper, gill-arch lever respiratory curve shows increase at first of rate and force, then gradual decrease. Lower, apex lever curve shows at once fall in force and rapid heart-beat that soon becomes irregular and spasmodic before ceasing.

Injection of different strengths of NH_4Cl solutions show that weak solutions are quite indifferent. An m/8 solution increases blood pressure and force of respiratory movements, but an m5/8 depresses cardiac and blood pressure activities and greatly stimulates the expiratory phase of respiration, causing an irregular spasmodic rhythm for fifteen minutes, and this is replaced by a weak but regular activity.

TABLE X. Effect of NH_4Cl solutions.

Salt. mol.	Heart rate.	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.	Pressure changes.	Curves.
NH_4Cl m/64	Unchanged or less.	Unchanged.	3 min.	Unchanged or increased.	Unchanged or less.	5 min.	26	26	
m/8	Unchanged or less.	Unchanged.	15 min.	Unchanged.	Expiration increased.	15 min.	26	28	40
m5/8	Much less.	Much less.	15	Long expiratory, irregular.	First increase, then regular or less.	15	26	22	41

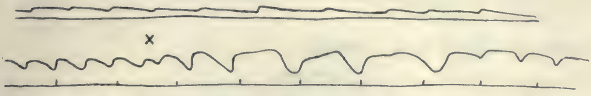
CURVE 40. Influence of NH_4Cl m/8 on cardiac respiratory and blood-pressure changes.



Upper, Hürthle cardiac and blood-pressure curves show that rate and force are unchanged, blood pressure rose. Lower, respiratory curve; rate unchanged, force slight increase.

CURVE 41. Effect of m⅝ NH_4Cl.

Curve 41.



Upper, Hürthle cardiac and blood pressure show a decrease in cardiac activity and blood pressure. Lower, respiratory curve; for fifteen minutes prolonged expiratory phase and irregular rhythm, then weak but regular.

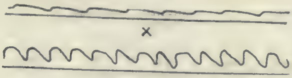
Effects of dehydrated chemically pure Na_2SO_4 solutions are most pronounced in the strong concentration of m/2 and m/1, both of which increase the force of cardiac, respiratory and blood-pressure activities, leaving the rate unchanged. The effect lasts longer with the weaker solution, and the aftereffects are not, as with the saturated m/1 solution, a weakening of the rhythm and fall in pressure.

TABLE XI. Summary of Na_2SO_4 effects on respiratory cardiac, and blood-pressure changes.

Salt mol.	Heart rate.	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.	Pressure change	Curves.
Na_2SO_4 m/64	Unchanged.	Unchanged.	15 min.	Unchanged.	Unchanged.	15 min.	26	26	42
m/2	Unchanged.	Slight increase.	15 min.	Unchanged.	Slight increase.	15 min.	26	27	43
m/1	Unchanged.	Slight increase.	5 min.	Unchanged.	Increased.	5 min.	27	29	44

CURVE 42. Effect of m/64 Na_2SO_4.

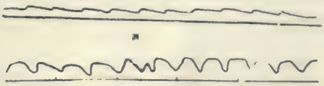
Curve 42.



Upper, Hürthle cardiac and blood-pressure curve, and lower, respiratory, all show no change after injection of the solution.

CURVE 43. Effect of m/2 Na_2SO_4.

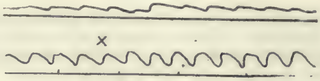
Curve 43.



Upper, Hürthle cardiac and blood-pressure curves; rate unchanged, force and pressure slight increase. Lower, respiratory curve; rate unchanged, force increased.

CURVE 44. Effect of m/1 Na_2SO_4.

Curve 44.



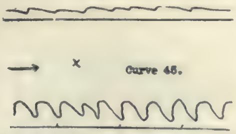
Upper, cardiac and blood-pressure curves, show slight increase in force and pressure, rate unchanged. Lower, respiratory; rate unchanged, force increased.

The effects of intravenous injections of $BaCl_2$ solutions are increased irritability and increased force and blood pressure, especially with weak solutions. Like most of the other salt solutions, it does not increase the rate of either heart or respiratory activity. In strong solutions it is toxic, producing at first irregular spasmodic cardiac and respiratory phases with strong diastolic and expiratory phases and with rise of blood pressure, or cessation of activity. The toxic effects can be avoided if small doses are injected with gradually increasing strengths, and the toxic effect is overcome by injections of $CaCl_2$ solutions.

TABLE XII. Effect of $BaCl_2$ on cardiac, respiratory and blood-pressure changes.

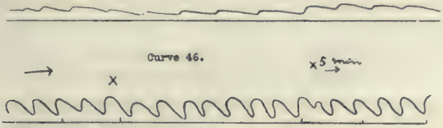
Salt mol.	Heart rate.	Heart force.	duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.	Pressure change	Curves.
$BaCl_2$ m/64	Unchanged.	Increased diastole.	15 min.	Unchanged or slightly less.	Expiration increased.	2 min.	18 mm.	20 mm.	45
m/32	Unchanged.	Unchanged or increased.	1 min. 8 min.	Unchanged.	Increased.	After 8 min.	16	16 18 14	46
m/8	Unchanged or slow or spasmodic.	Increased irritability.	2-5 min.	Stops or rapid spasmodic.		10-20 min. 2 min.	23	25	47
m/4	Toxic.			Toxic.					

CURVE 45. Effect of m/64 $BaCl_2$.



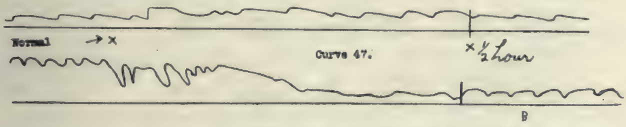
Upper, cardiac curve; rate unchanged, force and blood pressure slight increase. Lower, respiratory curve; rate unchanged, force increased.

CURVE 46. Effect of m/32 $BaCl_2$.



Upper, Hürthle cardiac curves; after one minute, rate, force and pressure unchanged. In five minutes, force and pressure increased. Lower, respiratory curve, shows rate unchanged, force increased.

CURVE 47. Effect of m/8 $BaCl_2$.



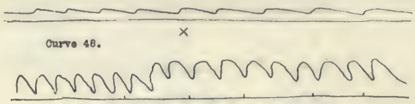
B half an hour after A. Upper curves of A and B, cardiac and blood-pressure records, show first spasmodic activity, then strong force and increased pressure. These activities decrease in half an hour but the rate continues unchanged. Lower, respiratory curve, shows first spasmodic action, then this stops for twenty minutes. In half an hour it is weak and slower.

The effect of distilled water passes off quite rapidly. For the first two minutes the rate of cardiac and respiratory activity is lessened and the force of the heart-beat and blood pressure slightly increased. The blood is rapidly affected and clots easily; soon the equilibrium of salts is again established and the normal action resumed.

TABLE XIII. Showing the effect of distilled water.

Distilled H_2O.	Heart rate.	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.	Pressure changes.	Curves.
3-4 cc.	Decrease.	Slight increase.	2 min.	Decreased.	Unchanged.	2 min.	24	26 24	48

CURVE 48. Effect of distilled water.



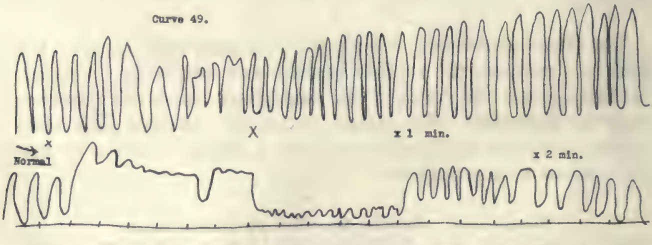
Upper, Hürthle cardiac and blood-pressure curves, show decrease in rate, slight rise in force and blood pressure for two minutes, then normal. Lower, respiratory lever, gill-arch curve, shows decrease in rate, force unchanged for two minutes.

Acid sodium phosphate solutions cause an increase in force of respiratory and cardiac activity, and for the weaker solutions at first also an increase in rate. Diastolic and inspiratory phases are often prolonged and the toxic effect is overcome by an alkali solution of sodium phosphate or one of $CaCl_2$.

TABLE XIV. Showing mean results of NaH_2PO_4 solutions.

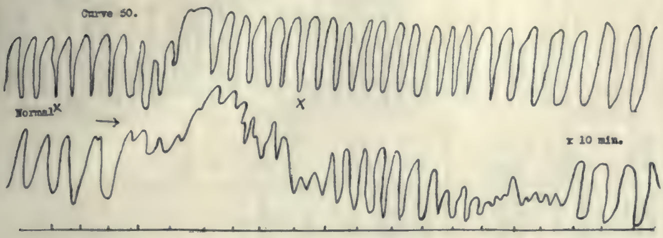
Mol. solution.	Heart rate.	Heart force.	Duration.	Respiratory rate.	Respiratory force.	Duration.	Pressure.	Pressure change	Curves.
m/64	Rapid to normal in two minutes.	Weak, increase.	1 min. 2 min.	Increased. Normal.	Less increase.	1 min. 2 min.			49
m/16	Increase.	Increase. Decrease. Normal.	1 min. 2d min. 10 min.	Unchanged.	Increased.	10 min.			50
m/8	Decreased. Normal.	Increased. Normal.	1 min. 5 min.	Increased.	Increased.	10 min.			51

CURVE 49. Effect of m/64 NaH_2PO_4 solutions.



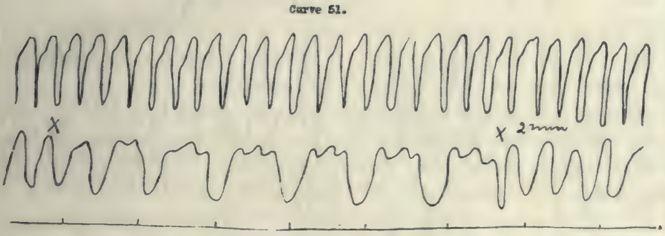
Upper records of respiratory activity before, during and following for two minutes the injection of an m/64 acid phosphate solution. First minute rate greatly increased, force less; within two minutes force gradually increased to slightly above normal and rate normal. The lower cardiac record shows first rapid contractions that increase during the second minute in force, becoming normal in rate and force in two minutes.

CURVE 50. Effect of m/16 NaH_2PO_4 solutions.



Upper, gill-arch lever records of respiratory activity, show increase in force, rate unchanged. Lower, cardiac lever, records first an increase in rate and force; second, rapid, shallow; in ten minutes quite normal in rate and force.

CURVE 51. m/8 NaH_2Po_4 solutions.



Upper, gill-arch lever records of respiration show increase in rate, and after two minutes also in force; inspiration prolonged. Lower, cardiac apex records. First minute prolonged diastole and increased force, followed by slower rate; in five minutes quite normal in rate and force.

TABLE XV. A general survey of the stimulating and depressing effects.

Stimulating. salt mol.	Heart force.	Heart rate.	Respiratory rate.	Respiratory force.	Blood pressure.	Duration.	Depressing salt mol.	Heart rate.	Heart force.	Respiratory rate.	Respiratory force.	Blood pressure.	Remarks.
NaCl m 1 m⅝	Increased.	Unchanged.	Unaltered.	Increased.	Rose.	m⅝ 5 min. m 1 15 min.	NaCl m/1	Less.		Less.	Unchanged.		
NaCl m 2	Rise.	Systole long.		Inspiration long.	Rose.	2 min.	NaCl m/2	Less.	After 2 min. less.	Less.	Less.	Fall after 2 min.	Weak sol. stimulates, Strong depressess.
KCl m/32 m/8			m/8 Rose.				KCl m/32 m/8	Less.	Unchanged.	Less.	Unchanged or less.	Unchanged or less.	m⅝ toxic. Depresses.
$CaCl_2$ m/32 m⅝	Rose.			Rose.	Rose.	1-3 min.	$CaCl_2$ m/32 ⅝	Unchanged or less.		Unchanged or less.			m⅝ depresses. Often toxic.
$MgSO_4$ m 24 m/1					Rose.	1-15 min.	$MgSO_4$ m/64 m/1	Less.		Less.	Less.		Depressing.
Na_2CO_3 m/32 m⅝	Rose.			m⅝ Rose.	Rose.	1-15 min.	Na_2CO_3 m/32 ⅝	Less.		Unchanged.	Unchanged.		Strong cardiac stim. and raises blood pres.
Na_2HPO m/64 m/4	m 8 Rise.						Na_2HPO_4 m/64 m/4		m/4 less.	Unchanged.	Less.	Fall.	Weak sol. stimulates, strong depresses heart force.
NaOH m/64 m/4	Rise.		m/8+m/4 Rise.		Rise.	5-15 min.	NaOH m/64 m/4	m/64 m/32 Less.			Less.		Strong sol. decreases force of respir.
Urea m/1 4m	Rise.			Rise.			Urea m/1 4m	Unchanged.		Unchanged.	Unchanged.		Strong sol. stim. force. Otherwise indifferent.
HCl m/64 m/32	Rise.			Rise.	Rise.	1 min.	HCl m/64 m/32	Less.		Less.			Weak stim. briefly. strong sol. depres.
NH_4Cl m/64 m8				m/8 Rise.	m/8 Rise.		NH_4Cl m/64 m8	Less. m⅝	Less m⅝			m⅝ less.	m⅝ depress., m/8 stim. expir. and blood press.
Na_2SO_4 m/2 m/1	Rise.			Rise.	Rise.		Na_2SO_4 m/2 m/1						Stim. force and press.
$BaCl_2$ m/64 m/4	Rise.			Rise.	Rise.		$BaCl_2$ m/64 m/4						m/4 toxic, weak sol. stim. force. Pres. prolonged diastole,
Distilled water.	Brief rise.				Brief rise.		Distilled water.	Less.		Less.			Brief stim. for blood press. and cardiac force.
NaH_2PO_4 m/64 m/8	Rise.	Rise.	Rise.	Rise.			NaH_2PO_4 m/64 m/8						Weak sol. stim. rate and force, prolong inspir. & diastole.

TABLE XVI. Toxic and Antitoxic Solutions.

Toxic.	Antitoxic.	Curves.
2m NuCl.	$CaCl_2$ m/32	3
m⅝ KCl.	m⅝ NaCl	11
m⅝ KCl.	$CaCl_2$ m/32	12
m⅝ KCl.	$CaCl_2$ m/4	13
m/1 $NMgSO_4$	$CaCl_2$ m/8	14
NaH_2PO_4 m/4	Na_2HPO_4, or $CaCl_2$ m/16	
m/1 Na_2SO_4	$CaCl_2$ m/16	
$BaCl_2$ m/4	$CaCl_2$ m/8	
$BaCl_2$ m/4	NaOH m/8	
NaOH m/16	HCl m/100	

The following is a *résumé* of the conclusions drawn from the different experiments:

M⅝ NaCl increases the force of cardiac and respiratory rhythm and blood pressure, but is indifferent to the rate during the first five minutes. Weaker solutions are neutral, and a stronger, m/1, solution is rather depressing except to heart force and blood pressure, while 2m is generally depressing, prolonging systolic and inspiratory phases.

The different strengths of KCl solutions proved depressing to the activities under consideration. Diastole and inspiratory changes are prolonged and the toxic effect of an m⅝ solution is counteracted by CaCl m/32 or NaCl m⅝.

$CaCl_2$ solutions are indifferent or depressing to the rate of both cardiac and respiratory activities, but stimulating to the force and slightly so to the blood pressure. M⅝ solutions prolong systolic and inspiratory phases.

Solutions of $MgSO_4$ are depressing to the respiratory mechanism and cardiac rate, but at first stimulate heart force and blood pressure. Diastole and expiratory phases are prolonged and the toxic effects are neutralized by m/8 $CaCl_2$ solutions.

Na_2CO_3 solutions stimulate heart force and blood pressure and are indifferent to the heart rate and the respiratory mechanism. Their stimulating effect upon the force of cardiac activity is enhanced when the solution is combined with urea, and like the latter exerts a similar influence upon respiration and heart action.

Na_2HPO_4 solutions stimulate as a rule only the force of heart action. The blood pressure, heart rate, as well as respiratory activities, are generally decreased or unaltered.

Solutions of NaOH proved more stimulating to cardiac force and blood pressure than any of the other solutions that were employed. They were depressing to cardiac rate and respiratory activity, except in strong solutions they increased the rate of respiration. They affect the center that controls the force of the heart-beat oppositely from what they do the center which governs the respiratory force. Like other alkaline solutions, they may exert their influence by favoring oxidation.

Urea solutions, except the strongest, are quite indifferent to the functions under consideration. A 4m solution increases the force of both the cardiac and respiratory activities; possibly through the OH ions that are set free when dissociation occurs.

Weak HCl solutions produce initial stimulations for a brief period in cardiac and respiratory force and blood pressure, but depress the rate, and a stronger, m/8, solution is toxic for cardiac but less so for respiratory activity.

Weak solutions of NH_4Cl are indifferent. An m/8 has a slight augmenting effect on blood pressure and the expiratory phase, while an m$\frac{5}{8}$ solution depresses blood pressure and cardiac rhythm, but heightens the force of the respiratory mechanism for a short time.

Following the injection of strong Na_2SO_4 solutions the force of respiration and heart action and height of blood pressure is increased, while the rate is unchanged. The addition of a weak solution of $CaCl_2$ is favorable.

The effect of a weak solution of $BaCl_2$ is increased force of cardiac and respiratory rhythm and a rise of blood pressure. Diastolic and expiratory phases are prolonged. The solutions are more toxic than other salts of the same concentration, and the toxicity is overcome by $CaCl_2$.

Injections of distilled water produce transient stimulating effects in the force of cardiac contractions and blood pressure, and depress the rate.

Weak solutions of NaH_2PO_4 accelerate the rate and force of heart and respiratory action. Diastole and inspiration are prolonged and toxic solutions are neutralized by Na_2HPO_4.

A consideration of the results tabulated in the foregoing pages discloses the fact that increased force of cardiac activity is usually accompanied by increased force of respiratory action and blood pressure. But NH_4CL m/8, urea, and Na_2HPO_4 are exceptions. NH_4Cl increases blood pressure without increasing cardiac force. Urea produced increased force of respiratory and cardiac activity without raising blood pressure, and Na_2HPO_4 m/8 increases force of cardiac but decreases force of respiratory action. Moreover, most of the salt solutions of a definite concentration that augmented the force of cardiac also increased the force of the respiratory rhythm and proved either indifferent or depressing in their influence upon the rate of both of these activities.

The exceptions are $MgSO_4$ m/8, which stimulates force of cardiac but not that of respiratory activities and is depressing to rate, and NaOH m/8, that stimulates cardiac force and rate but not the respiratory rhythm.

The toxic effect of many solutions at certain concentrations was counteracted by definite strengths of other salts. Of these antagonistic solutions, $CaCl_2$ m/32 or m/8 proved most extensively favorable. It was interesting to learn that certain concentrations of some salt solutions prolong the cardiac systole and the inspiratory phases, while other solutions favor diastolic and expiratory phases. M/2 NaCl and also m5/8 $CaCl_2$ prolong systole and inspiration, while KCl m/8, NaH_2PO_4 m/8 prolong inspiratory activity and diastole. Moreover, strong solutions of $MgSO_4$, NH_4Cl and $BaCl_2$ prolong diastole and expiratory activity.

The salts that were especially depressing upon the cardiac and respiratory phases were KCl and $MgSO_4$. There are certain optimum per cents of salts and acid solutions, below or weaker than which the effect is stimulating or initiates temporarily increased activity, and above or greater concentration than which the solution inhibits or decreases activity or proves toxic. Moreover, increased blood pressure, as a rule, is accompanied by a decrease in rate of cardiac and respiratory activity.

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THE NUTRITION OF THE EMBRYO SAC AND EMBRYO IN CERTAIN LABIATÆ, ... *F. H. Billings.*

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THE NUTRITION OF THE EMBRYO SAC AND EMBRYO IN CERTAIN LABIATÆ.

BY F. H. BILLINGS.

Plates XI to XIV.

SOON after the publication of a paper on seed development, in which various sympetalous families were considered, the writer began an investigation of embryo-sac nutrition as found in the Labiatæ. Literature upon the subject indicated the presence of certain nutritive structures that resembled some of those described in the paper mentioned above. The structures consisted of outgrowths or specialized portions of the embryo sac which by enlargement frequently replaced considerable portions of the integument. The position and shape of the structures are characteristic in some instances of the family in which they occur. It is therefore one of the problems of the present investigation to ascertain what degree of uniformity prevails among a number of genera of the Labiatæ, and thus determine, if possible, whether any special type of embryonic structure is liable to become characteristic of the family. Though the number of species studied is but a small representation of the total number distributed over the earth, still, as will presently be shown, a great enough similarity exists among them to warrant the supposition that a like resemblance probably exists among the remainder. It would not be safe to extend such a conclusion to any family taken at random, inasmuch as some families are aggregates of groups, such as subfamilies, which may not be closely allied phylogenetically but which are associated on account of fulfilling certain taxonomic requirements.

One of the services that may ultimately be performed for taxonomy is that of testing the homogeneity of families. The results could be reached satisfactorily only after all the species of any given family had been examined as to their ontogeny. Taxonomically speaking, the Labiatæ are regarded as a fairly homogeneous family with well-marked characteristics.

Species whose common ancestors are not remote should show similarity in embryonic particulars, since these are doubtless the ones least influenced by environment.

No attempt was made to work out the stages preceding fertilization in every instance. Several species were examined, however, and the series of events constituting the earlier history of embryo-sac development were found to be identical.

The ovular primordium gives rise to a single megaspore mother cell, from which originates an axial row of four potential megaspores. The most deeply seated of the four develops into the ordinary type of an eight-celled embryo sac.

The growth of the embryo was followed in detail in *Lamium amplexicaule,* and it was found that the various stages in development correspond closely to the plan observed in most dicotyledonous embryos. However, it is not with the development of the embryo but with the behavior of the embryo sac that this paper has most to do.

Many of the writings of early investigators who worked along embryological lines show that there was little thought of assigning physiological significance to peculiar shapes assumed by the embryo sac. More recently quite a number of observers have entered the field, and they have shown the wisdom of correlating morphology and physiology. Bibliographies of their papers have been published from time to time, so that only the literature cited in the text, or very recent papers, will be given here.

The single and unusually thick integument of many Sympetalæ, including the Labiatæ, appear to serve a double function. The outermost layers become transformed into a seed coat, while the inner or remainder, wholly or in part, may become a nutritive tissue (Nährgewebe) which invites, as it seems, the digestive and absorptive activity of the endosperm. Sometimes the nutritive tissue is more or less localized, as can be seen from the deposits of starch in certain regions. In other instances the deposition of food material is general throughout the integument, so that no special part would be likely to become a particular point of attack by the endosperm.

When the absorptive activity of the endosperm is largely centered in some outgrowth or differentiated portion of the embryo sac, the term "haustorium" is applied to such a portion. In instances where haustoria are not developed, the digestive and absorptive power is more or less equally distributed over the entire surface of the embryo sac. Where absorption is going on most rapidly, the cells directly concerned in the appropriation of the nutritive material are usually abundantly supplied with plasmatic contents. In case of the presence of a haustorium the endosperm cells lying adjacent to the base of the haustorium show the greatest richness in plasmatic contents.

The following genera and species of Labiatæ form the bases of the detailed description:

Lamium amplexicaule.
Stachys palustris.
Phrysostegia virginiana.
Leonurus cardiaca.
Brunella vulgaris.
Teucrium canadense.
Pycnanthemum lanceolatum.
Lycopus rubellus.
Mentha canadensis.
Salvia lanceolata.
Salvia azurea.
Monarda fistulosa.
Nepeta cataria.
Dracocephalum sp.
Scutellaria parvula.

Lamium amplexicaule.

This species will be given more detailed consideration than the others, for it will serve in a measure as a type of the family and also as a basis of comparison for the other species. The embryo sac, at the time fertilization is accomplished, contains the usual form of egg apparatus (fig. 1). The endosperm nucleus is large, spherical in form, and contains a vesicular nucleolus. The nucleus does not lie near the egg apparatus, as is the case in so many plants, but at the opposite end of the sac near the disintegrating antipodals. The contour of the sac shows a constriction which may be used to distinguish a larger upper, or micropylar portion, in which the egg apparatus lies, from a smaller, lower, or antipodal portion, in which the endosperm nucleus lies. The endosperm nucleus does not leave the antipodal region, but immediately after fertilization develops a tissue in its end of the sac. Double fertilization probably occurs, though it was not observed.

The egg responds to fertilization by elongating greatly, and pushing down into the forming endosperm tissue (figs. 2, 3). The elongation is at first due to the growth of the entire egg cell. A transverse wall soon separates the suspensor from the proembryo. It is thus seen that the cell which is to develop into the embryo is removed altogether from the micropylar portion of the sac. For a time this portion contains no active nuclei, the synergids being in a process of disintegration. But endosperm nuclei soon migrate into it through the space lying between the suspensor and the wall of the embryo sac. The nuclei are but few in number and they do not form tissue (fig. 4). From this time on, the two extremities of the embryo sac are very sharply distinguished. The antipodal end is soon filled with a compact growing tissue that surrounds the embryo. Increase in size of the tissue takes place rapidly, so that the micropylar portion shortly becomes the smaller (fig. 4). A remnant of nucellus can usually be seen as a disorganized mass of cells lying at one side of the micropylar expansion of the sac. For a considerable length of time the endosperm tissue extends only to the constriction, beyond which lies the micropylar region with its wandering endosperm nuclei. An examination of the integument cells surrounding this region shows that dissolution is in progress—due, of course, to the predatory activity of this part of the sac. The antipodal portion, with its endosperm tissue, exerts a similar absorptive influence, but the material absorbed by the latter is retained or used up in building more tissue, while that absorbed by the former is not, but is transferred to the endosperm tissue. The micropylar portion of the embryo sac may therefore be regarded as a haustorium. Evidence of the results of haustorial activity is seen in the unusual richness of plasmatic contents in the endosperm cells bordering on the haustorium. The presence of starch in the basal portion points to the same conclusion.

The nuclei of the haustorium do not form tissue, as has already been stated. In *Lamium amplexicaule* they take no definite position. Although they have the same origin as the nuclei of the endosperm tissue they differ considerably from them. The chief difference lies in their much greater size. These may attain a length of over thirty micromillimeters, which is greater than the average diameter of an endosperm cell (fig. 5). The haustorial nuclei vary usually from twenty to thirty micromillimeters in diameter, but the smallest are much larger than any formed in the endosperm tissue, since these average only about five micromillimeters in diameter. Another difference is the much greater size of the nucleoli of the haustorial nuclei. In addition, the nucleoli are not vesicular, as are most of those in the endosperm tissue, but are solid. The large size of the nucleoli would seem to indicate an increased nutritive function on the part of the nucleus, especially in light of the theory that nucleoli represent reserve food substance. There is no evidence that the haustorial nuclei undergo division, either in *Lamium* or in the cœnocytic haustoria of any other of the Labiatæ investigated. There is some variance in the explanations of the peculiarity of these nuclei, but discussion of them will be reserved till the close of the paper.

The suspensor elongates during the growth of the embryo sac and finally attains an unusual length (fig. 6). Its course is for some time plainly visible in the haustorium and for a longer time in endosperm tissue. The portion nearest the embryo persists while the remainder slowly disintegrates. The appearance of the suspensor is such that at no time does it seem to serve as a conductor of food substances to the embryo, at least from any locality other than that of the endosperm tissue immediately surrounding it. It appears to have fulfilled its function when it carried the embryo from the haustorium down into the midst of developing endosperm tissue.

While the micropylar haustorium is transferring materials to one end of the endosperm tissue the opposite end is nourished by substances conducted through a vascular bundle that passes down the integument and terminates near the chalaza. The little depression or pocket in which the antipodals undergo disintegration is deepened until it forms a short canal, which extends from the endosperm toward the terminus of the vascular bundle. It does not merit the name of haustorium to the extent that the micropylar expansion of the sac does, since it exerts little or no absorptive influence upon the integument cells bordering it, but rather seems designed to facilitate conduction from the bundle. Its increase in length is not accompanied by a pronounced increase in diameter nor does it contain nuclei.

Later stages in embryo development show increase of the endosperm tissue and a consequent encroachment upon the haustoria. Just when the micropylar haustorium ceases to function is hard to say. Its activity probably does not cease as soon as it begins to be encroached upon by the endosperm tissue. The nuclei in fact remain till late stages in seed development.

Stachys palutris.

The embryo sac seen in figure 7 presents markedly differentiated portions. The stage shown here is reached in the same manner as a corresponding one in *Lamium.* While the endosperm is beginning its formation in the antipodal end of the sac a number of nuclei migrate into the haustorium. They distribute themselves over the micropylar end of the haustorium, where the cytoplasm is chiefly located. The opposite end is distinctly vacuolated. It will be noticed that the constriction is very narrow. Through it passes the suspensor with an enveloping layer of cytoplasm. The regions adjacent on each side of the constriction are stored with starch, the result evidently of the absorptive activity of the haustorium. As in *Lamium,* the cells of the endosperm tissue nearest the haustorium are richer in plasmatic contents than those at a distance.

The canal that conducts from the terminus of the vascular bundle is comparatively long in *Stachys.* It is sharply bent about midway in its course, one arm running longitudinally to connect with the end of the vascular bundle.

Stachys and *Lamium* vary in the structure of their embryo sacs only in minor details, the main difference being the more definitely placed haustorial nuclei in *Stachys.* The embryo is nourished in both by the endosperm tissue surrounding it, this in turn being assisted in its growth by the activity of the haustorium. It is probable that the suspensor does not function in the conduction of materials to the embryo, on account of the disorganized condition of its cells. The food materials gathered by the haustorium are transmitted to the endosperm tissue through that part of the constriction lying around the suspensor.

Phrysostegia virginica.

This species has a peculiar appearing embryo sac when the stage shown in figure 8 is reached. Such difference as may be noted, when it is compared with *Lamium* and *Stachys,* is due principally to the direction of growth taken by the endosperm tissue. If the growth had been uniform in all directions the long axes of the haustorium and endosperm tissue would have been approximately parallel. In *Phrysostegia* the endosperm grows in a one-sided fashion, producing a bend in the embryo sac of about ninety degrees. The haustorium is a club-shaped sac containing a few large nuclei. Its upper or micropylar end is vacuolated, while its lower end, adjoining the endosperm tissue, is densely protoplasmic. The suspensor is exceedingly long.

The position of the antipodal canal is peculiar in this species. It is located near the haustorium—a situation explained by the short length of the vascular bundle, as well as the one-sided growth of the endosperm tissue. The constriction existing between the haustorium and endosperm tissue is comparatively wide, with the result that the cytoplasm of the haustorium comes in contact with the endosperm tissue to a greater extent than in any other species examined.

Leonurus cardiaca.

Leonurus has a large haustorium with a contour much like that of *Stachys* (fig. 9). The haustorial nuclei have a more or less fixed position in that portion lying nearest the endosperm tissue. This is the reverse of the condition in *Stachys,* where the nuclei lie in the micropylar region. Their number varies from four to six. The definite position of the haustorial nuclei would suggest the presence of cell walls, but there was no evidence of them.

Leonurus bears a close resemblance to *Phrysostegia* in the proximity of the antipodal canal to the haustorium. The canal does not appear in the section shown in figure 9, so its position is indicated by the dotted lines. The lower portion of the endosperm tissue and its connection with the vascular bundle through the canal is shown in figure 10.

Brunella vulgaris.

This species possesses a large cœnocytic haustorium containing nuclei without definite position. In this respect it is like *Lamium.* The antipodal haustorial canal becomes laterally placed, but, unlike the two previously described genera, it remains near the base of the endosperm tissue.

The five genera thus far mentioned belong to the tribe Stachydeæ. No marked variations occur; in fact, they are much more nearly alike than they are different. *Phrysostegia* appears to be the most divergent, but such divergence is really trivial. All are characterized by a large micropylar haustorium—a feature, however, which it shares with representatives of other tribes.

Teucrium canadense.

A glance at the diagram shown in figure 11 will show the relative position and size of the different portions of the embryo sac. The most noticeable difference between this species and those previously described is the relatively small size of the haustorium. The failure of the haustorium to enlarge much is doubtless mainly due to its proxity to the end of the beak-like extremity of the integument. There is but little room for enlargement. The haustorium contains a few nuclei that do not form a tissue. Whether this organ is really functional or not is difficult to determine with certainty. At most its activity can be only very slight, otherwise the extremity of the integument would undergo dissolution. The endosperm nuclei which are found in it do not have the size nor the altered appearance seen so frequently in vigorously acting haustoria. It would appear from this that alteration in the haustorial nuclei is to some extent at least proportional to the activity of the organ to which they belong.

Pycnanthemum lanceolatum.

The general configuration of the embryo sac is much like that of *Lamium* (fig. 12). The cœnocytic haustorium attains a large size, with the result that most of the micropylar portion of the integument becomes absorbed. The constriction between haustorium and endosperm tissue is soon obliterated, so that the two lie contiguous over a considerable area. The suspensor is long, as in the previously mentioned species, but owing to the size of the haustorium most of its length is found within the limits of this structure.

Lycopus rubellus.

Lycopus rubellus, when contrasted with *Pycnanthemum,* which belongs to the same tribe, differs in two respects; the haustorium is small, and the constriction lying between it and the endosperm tissue is relatively long (fig. 13). The basal portion of the endosperm tissue extends in a beak-like process to the end of the vascular bundle. This process occupies the position of the antipodal canal of previously described species. Its origin may be explained by a growth of the tissue into the canal, which it thus displaces. The haustorium contains but one or two nuclei with no formation of tissue.

Mentha canadensis.

The integument in this species is not extensive, yet there is a large cœnocytic haustorium present which closely resembles that of *Pycnanthemum.* Like *Pycnanthemum,* there is in *Mentha* an early obliteration of the canal connecting haustorium and endosperm tissue. *Lycopus,* on the other hand, represents the other extreme, in which the canal persists for a long time. *Pycnanthemum, Lycopus* and *Mentha* belong to the tribe Satureineæ.

Salvia azurea and *Salvia lanceolata.*

These two species will be considered together, as they present many points in common. As compared with the representatives of other genera, however, they show marked differences. In the first place, they are unique in having two haustorial outgrowths, one cœnocytic and one composed of ordinary endosperm tissue. In addition, there is a well-developed antipodal canal.

In order to follow better the development of the haustoria, it will be advantageous to examine the definitive embryo sac and consider some of the phenomena immediately following fertilization. The definitive embryo sac of *Salvia lanceolata* is shown in figure 14. It is short, and in comparison with the extensive integument is relatively insignificant (fig. 15). The shortness is the more noticeable when the amount of space occupied by the egg apparatus is taken into consideration. The embryo sac is filled with a reticulated cytoplasm, which is distinguished from that of *Lamium amplexicaule* and other species examined by the absence of vacuoles. The antipodals lie in the depression which marks the beginning of the canal to the vascular bundle. The small size of the embryo sac necessitates the proximity of the endosperm nucleus to the egg apparatus.

Fertilization is followed by a very *slight* elongation of the egg cell—a marked variation from the condition found in the species of other genera examined. The explanation for this difference lies in the fact that none of the space occupied by the definitive embryo sac is to be included in haustorium formation, since elongation of the egg and suspensor is always for the purpose of removing the embryo from the sphere of haustorial activity. In *Lamium* approximately half of the sac becomes haustorium, and it is in view of this fact that the embryo is transferred for development to the antipodal region. The elongation of the suspensor in the majority of Labiatæ examined appears to terminate its function, for disintegration follows. In *Salvia,* on the contrary, there is reason to believe that it plays an important part in embryo nutrition. The cells composing it are short and relatively rich in plasmatic contents.

The first division of the endosperm nucleus results in the formation of a cell at the extreme antipodal end of the embryo sac. The wall cutting off this cell lies approximately in a plane at right angles to the long axis of the embryo and suspensor. The separating walls of cells produced in succeeding divisions are at first parallel to the first wall. The embryo is soon surrounded by endosperm tissue (fig. 16). One endosperm cell takes a position near the end of the suspensor for the purpose of entering directly into the formation of a haustorium. The growth of the endosperm tissue surrounding the embryo is greatest in a direction toward the upper part of the integument and approximately parallel with the vascular bundle. As a result, an endosperm process, cylindrical in shape, projects into the region where lies the most extensive portion of integument tissue (fig. 17). The outgrowth is evidently designed to reach the nutritive tissue remote from the main mass of endosperm. Functionally, it is a haustorium, differing principally from tissue-containing haustoria of certain other families of plants in the greater number of cells. Figure 17 shows a young haustorium of *Salvia lanceolata.* In its maturer stages, seen diagrammatically in figure 19, it is composed of much elongated cells. Such differentiation suggests conduction as a function. The elongated cells lie principally in the axis of the haustorium with their long axes parallel to that of the haustorium. The peripheral cells serve as digestive and absorptive cells, while those of the interior of the haustorium are conductive. The products of its activity are transferred to the main mass of endosperm which it thus serves as an absorbing organ.

The other haustorium is cœnocytic, and its activities are directly concerned with embryo nutrition through the suspensor. It is not a structure developed from the suspensor, though it continues it, in a way, out into the integument. It recalls some of the haustorial outgrowths in the suspensor cells in certain Orchidaceæ[2] and Rubiaceæ.[3] In *Salvia lanceolata* two endosperm nuclei take part in haustorium formation; more than two in *Salvia azurea* (fig. 18). In both species one end of the haustorium completes the basal or proximal portion of the suspensor. In *Salvia lanceolata* more of the suspensor is surrounded than in *Salvia azurea.* In the former the suspensor becomes bent while in the latter it remains straight.

The haustorium grows outward through the integument, taking a direction nearly at right angles to that taken by the other haustoria. The purpose of the cœnocytic haustorium is to dissolve the integument cells surrounding it, but it is unique in communicating the products of its activity to the suspensor. Attention has already been called to the striking differences between the *Salvia* suspensors and those of the other Labiatæ examined. As the former take part in embryo nutrition their cells present an appearance betokening activity. Instead of losing their protoplasmic contents or undergoing dissolution, as in instances where excessive elongation takes place, the suspensor cells of *Salvia* are healthy appearing, resembling the endosperm cells in this respect not a little.

The cœnocytic haustorium does not attain the size of the one composed of tissue (fig. 19). As in similar haustoria previously described, the nuclei are larger than those of the endosperm tissue.

A canal, bent at nearly right angles, is formed between the endosperm and the vascular bundle. There appears to be no nucleus in it, but granular material resembling cytoplasm is found along the side walls and at the end. As the main body of endosperm pushes outward at the expense of the integument cells, the canal does not suffer for a time (fig. 20). Instead, the endosperm becomes laid down around its proximal end. This gives the appearance of the canal piercing the tissue. The canal forms a direct communication with the vascular bundle, serving probably as a conduction to the endosperm.

Monarda fistulosa.

This species is patterned after *Lamium* rather than after *Salvia.* There is a large cœnocytic micropylar haustorium which does not differ materially from that of *Lamium.* A few nuclei are present, though of a relatively smaller size. The embryo sac is narrow and the suspensor is very long. There is no antipodal canal, but the endosperm tissue bends toward the terminus of the vascular bundle in the form of a process.

Nepeta cataria.

The haustorium of *Nepeta cataria* is cœnocytic, and contains four nuclei that occupy a more or less definite position at its base or near the place where the suspensor passes into the constriction (fig. 21). The haustorium is relatively small, containing much less than half the length of the suspensor.

Dracocephalum sp.

This varies from the other species of Labiatæ examined in the character of the outline of the endosperm tissue. In the other species this tissue enlarges quite uniformly, presenting a smooth or entire outline when sectioned. The outgrowths in *Dracocephalum* have no definite position or form and hence are not to be regarded as other than integral portions of the endosperm tissue and not haustoria (fig. 22). The haustorium is much elongated, as is the endosperm tissue. The embryo lies in the upper portion of the latter, being attached at the end of a very long suspensor.

Scutellaria parvula.

The bent embryo sac of *Scutellaria*, resulting in a bent embryo in the ripe seed, is of course well known to taxonomists. It conforms to the other species in Labiatæ in possessing a haustorium, but located, as it is, at the extreme tip of the ovule, its growth is greatly limited, so that it remains small (fig. 23). The endosperm is elongated and tapers at the base into a hook-like process whose end lies near the terminus of the vascular bundle.

DISCUSSION AND CONCLUSIONS.

In a large number of plants, especially those in which two integuments are present, the embryo sac assumes a somewhat elliptical or oval form in longitudinal section, with an approximately entire outline. The nutrition designed for growth of the endosperm may be absorbed fairly uniformly over the entire surface of the sac, or it may be absorbed more rapidly at one point than at other points, but in either case the elliptical or oval outline is maintained. If added organs mean increased specialization, then embryo sacs of the type just mentioned, without special absorptive structures, may be regarded as a simpler, less differentiated, perhaps more nearly primitive, sort.

In some instances the innermost cell layer of integument, which borders on the nucellus or else on the embryo sac, is specialized into a digestive layer, whose activity is directed against the remaining integument for the benefit of the embryo sac. The name "tapetum" has been frequently applied to this layer, but its use is justified only on account of the nutritive function it performs. Goebel[4] proposes the term "epithelium" as a substitute. Three characteristics usually pertain to the epithelium: first, it remains intact for a longer period than the integumental layers adjacent; second, its cells become differentiated in form or contents from those of the remaining integument; third, it apparently exerts a digestive action. The digestive action is doubted by some, among whom is Schmid,[5] who ascribes a protective function to it. Since the species of Labiatæ herein described do not develop an epithelium, it is without the province of this discussion to do more than call attention to the fact that Schmid challenges the results obtained by the "Goebelische Schule," thus showing that the problem is open for further investigation.

The Labiatæ, in common with some other sympetalous families, depart from the type described for many plants having two integuments by differentiating haustoria. The haustorium implies increased absorptive activity in one portion of the embryo sac, but not necessarily cessation of the function elsewhere. Among the labiates studied, all (with the single exception of *Salvia*) have a micropylar haustorium of some sort. In most of the species it is a well-developed structure, exhibiting manifest activity as a nutritive organ. But in such species as *Scutellaria parvula, Teucrium canadense,* and *Lycopus rubellus,* it is of small size, and its usefulness may with safety be said to be either greatly reduced or else obsolete. Whether such a condition really represents actual reduction from a previously more highly developed state, or whether it is primitive in its nature, is a problem yet to be solved. The much elongated suspensor is here offered as evidence favoring the former view, since the purpose of elongation is believed to be the removal of the embryo from the region of the haustorium. Extraordinary length in proportion to the size of the haustorium might therefore mean that shortening of the former did not accompany reduction in size of the latter. Conditions external to the embryo sac may have had something to do with haustorium reduction in such a species as *Scutellaria parvula,* where narrowing of the integument to a beak left but little tissue to be exploited.

The nuclei in the cœnocytic haustorium merit interest on account of the extraordinary size and appearance some of them attain. Such nuclei are found in other families where similar haustoria exist. They have been described by Balicka-Iwanowska,[6] Schmid[5] and others. That they are transformed endosperm nuclei is of course easy to observe. Knowing the kind of work the haustorium is called upon to do, one might expect increase in size, both of entire nucleus and also of nucleolus, on account of extraordinary nutritive function. The loss of power to divide accompanies the development of this function. According to Schmid,[5] the nuclei should be considered degenerate structures, whose condition has been produced by excessive nourishment, as is attested by loss of power to divide. Instances of like nature are not limited to embryo sacs, but occur in mycorrhiza and in animals. There is room for difference of opinion, however, as to the governing principle underlying such nuclear change. It is at least open to investigation whether the increase in size is a direct result of degeneration, due to unusually favorable conditions regarding food supply, or whether it is due to the added functional responsibility demanded of them by the haustorium. It is questionable whether either failure to undergo division or exceptional abundance of nutriment should be used as a test of degeneracy. As evidence against the latter view, attention is called to the normal appearance of the nuclei in the cellular haustorium in *Salvia* and those in the endosperm cells adjacent to a cœnocytic haustorium. Both are in very favorable condition as to food supply, yet there is no nuclear enlargement. It would appear that cœnocytic structure is conducive to such enlargement, but it cannot be merely a question of food supply. A difference is to be noted in the lack of cell walls, which in a tissue may possibly exert a limiting influence on increase of size in nuclei. Another difference is seen in the relatively small number of nuclei in a cœnocytic haustorium. It might be difficult to prove, however, that for this reason the work demanded of each nucleus would be greater, though of course there is a possibility that it might be true.

Haustoria have either indefinite or more or less definite positions of their nuclei. Walls might be expected in instances where the nuclei are definitely placed. Balicka-Iwanowska[6] found a very delicate gelatinous membrane present in certain instances of this sort. No walls were evident, however, in any of the micropylar haustoria of the Labiatæ.

Indefinite location of nuclei are associated with irregular form of haustorium, while those having a more nearly fixed position are found in such as have an approximately symmetrical form.

The Labiatæ investigated generally have long suspensors, which are associated with the presence of micropylar haustoria. An exception is seen in *Salvia,* which has a short suspensor and no micropylar haustorium. The direct results of suspensor elongation are the removal of the embryo from the haustorium and its transfer to the vicinity of the center of the growing endosperm tissue. These results are doubtless sufficient to serve as causes for suspensor elongation. It is at least evident that a position within the haustorium would not be as favorable as a position without in so far as the products of haustorial activity are concerned. The endosperm tissue itself exerts a digestive action on the integument, and it also receives the nutriment from the haustorium, hence this tissue is more favorable for embryo development than the haustorium alone. Although integument cells are destroyed by the haustorium, there is no reason for believing that those of the embryo would likewise be, since endosperm tissue bordering on the haustorium is in no way affected by its digestive action. There is, therefore, no reason for thinking that suspensor elongation is to remove the embryo from the predatory action of the haustorium.

In general, it does not appear that the suspensor functions as a conductor of nutrition to the embryo. Evidence for this view is found in the collapsed condition of the suspensor through nearly its entire length, especially in that part lying within the haustorium. The greater portion of it is apparently without cell contents of any sort, and may or may not be continuous from the micropylar end of the embryo sac to the embryo. It would be expected of a cell or tissue that is serving actively as a means of translocation of food materials that some vestige of life would be discernible. In *Salvia,* for instance, a healthy, vigorous condition of the suspensor cells accompanies activity in food transmission. In all the species examined (except *Salvia*), the only suspensor cells that appeared to be living were those immediately adjacent to the embryo. The nutrition of the embryo is accomplished through absorption over its entire surface, whereas in *Salvia* an added source of nutriment probably lies in the conducting power of the suspensor.

The length of the suspensor is roughly proportionate to the size of the haustorium through which the embryo has to be transported. Usually the movement is past a cœnocytic structure to a tissue. An instance is to be noted, however, in *Myoporum*[1] (Myoporaceæ), in which the growth is directly through one portion of the endosperm to another. The beaked portion of the endosperm is apparently a remnant of what may once have been a cœnocytic haustorium, but in which the cœnocytic condition has been lost.

The integument varies in thickness and extent in the different species. Of course, it is in those in which it is most extensive that the largest haustoria are possible. Through the integument in each case there runs a vascular bundle which terminates near the antipodal region. A slight outpocketing of the embryo sac is found extending into the integument toward the end of the bundle. Later it may develop into a canal without nuclei, or into a process of the endosperm. Its function in all cases is evident—to facilitate the passage of nutriment from the vascular bundle to the endosperm.

In summing up the characteristics that are common to the species described in this paper, with the exception of *Salvia,* they have been found to possess three that in the future may be shown to belong to the family as a whole. They are the micropylar haustorium, the much-elongated suspensor, and the antipodal canal or process. Marked variations from a common type, such as are found in *Salvia,* suggest a taxonomic rearrangement, even though the usual macroscopic characteristics resemble those of the family in which the varying species is placed. In a previous paper,[1] for instance, attention was called to the striking difference in the ovular structure of the Menyantheæ when compared with the coördinate subfamily

Gentianeæ. The two have since been raised to family rank, probably for other reasons, yet it is interesting to note that the structure of the ovule justified the wisdom of the change. In this way can a study of sporangial, gametophytic and embryonic structures be of service in establishing more natural relationships and groupings.

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Mitosis in the Root-tip Cells of Podophyllum peltatum, *A. Richards.*

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MITOSIS IN THE ROOT-TIP CELLS OF *PODOPHYLLUM PELTATUM.*

BY A. RICHARDS.

Plates XV and XVI.

(Contribution from the Botanical Laboratory of the University of Kansas.)

THE work, the results of which are herein presented, was undertaken during the summer of 1907, under the direction of Prof. W. C. Stevens, whom I have to thank for his kindness and much helpful advice. My thanks are also due Mr. F. A. Hartman for helpful suggestions.

In discussing the root-tip cells of *Podophyllum peltatum,* I shall use the following outline:

I. Methods.
II. Resting cells.
    A. Nucleus.
        1. Nuclear membrane.
        2. Chromatin.
        3. Achromatin.
        4. Nucleolus.
    B. Cytosome.
        1. Cell wall.
        2. Cytoplasm.
        3. Archoplasm.
III. Dividing cells.
    A. Prophase.
        1. Nucleus.
        2. Cytosome.
    B. Later phases of division.
        1. Chromatin.
        2. Achromatin and cytoplasm.
IV. General considerations.
    A. Achromatic and archoplasmic structures.
    B. Individuality of chromosomes.

METHODS.

The root-tips of *Podophyllum peltatum* are peculiarly fitted for the study of mitosis in the vegetative cells of plants. The cells are larger than those of the onion root-tip, and in properly stained material the cell organs, especially the chromosomes, are to be seen with almost diagrammatic clearness.

The material used in this study was collected during the latter part of March and fixed in Flemming. For staining the sections three methods were used: Haidenhain's iron-hæmatoxylin (some sections counterstained with orange G), the safranin-gentian violet-orange G stain, and a combination of these two. Satisfactory results were obtained with slides stained in hæmatoxylin, both with and without the counterstain; the three-color method also gave fair results. Only a few sections were successful with the combination method, but they were promising; without doubt the method will repay careful experiment. It was followed as given by Schaffner (2).

THE RESTING CELL.

The most typical resting cells are not often to be found at the tip of the root, for this, of course, is the region of greatest mitotic activity and the resting stages are very short, but back from the tip as much as two millimeters. Farther from the tip the cells are apt to be plasmolyzed in fixing.

The nuclear membrane of the resting cell normally disappears as soon as the cell begins division; it is, however, quite constant in its appearance and staining reaction, and varies only slightly in thickness. It appears to stain very deeply with chromatin stains, a fact which is probably due to the peripheral arrangement of the chromatin granules, as seen in figure 1. These chromatin masses are arranged over the linin network of the nucleus in large or small patches, depending on the age of the cell, *i. e.*, nearness to the tip.

In examining the achromatic structures of the cells of *P. peltatum* I have had considerable difficulty, especially in the stages of mitosis. In some cells they can be seen quite clearly; in others, which appear to be equally well fixed and have been treated with exactly the same methods, they cannot be seen at all. Owing to this irregularity in their staining capacity, I have not been able to work out their history accurately.

The nucleoli of these cells are very interesting. They vary in number from one to several—rarely more than four—and in size and shape. In general they are irregular-spherical, but may be compressed into different shapes. The variation in size, which is considerable, depends on the age of the cell. As the time for division approaches they grow smaller, finally disappearing about the same time as the nuclear membrane. This last fact sustains the conclusion that the nucleolus is simply a storehouse for food material for the rest of the cell.

In most cells up to the time of division there is noticeable a peculiar vacuolated condition of the nucleus, and in these vacuoles lie the nucleoli. Figure 1 shows two such cells, one of which has a single large nucleolus surrounded by a vacuole and the other three. The term "vacuole" for the clear space surrounding the nucleoli may be misleading. Experiments seem to show that this colorless space contains something more than a watery fluid, which is extracted by dehydration. By subjecting the roots of *Zea mays*, *Vicia faba*, and other plants to strong centrifugal force, Mottier (1) found that the nucleolus with its surrounding clear space was thrown out of the nucleus into the cytoplasm. "The nucleolus was still surrounded by the space, a fact that seems to show that the colorless substance has greater specific gravity than the other contents of the nucleus. The colorless substance may represent the unorganized nucleolar material."

The cell wall of the resting cells stains much like the nuclear membrane and is only slightly thicker.

The cytoplasm stains fairly dark with iron hæmatoxylin, and shows its fine reticular structure quite plainly. Scattered uniformly over the threads of the reticulum are large granules. The cytoplasm of the cell stains slightly denser than the nuclear sap.

With regard to archoplasmic structures, not the slightest evidence was seen to indicate that such structures as have been described by Schaffner are ever present: *i. e.*, centrosomes and centrospheres.

DIVIDING CELLS.

The plane of division in these cells is mostly at right angles to the axis of the root. This rule, however, is by no means invariable, for numerous cases have been found with the division planes parallel to, or at an angle of forty-five degrees with, the longitudinal axis (figs. 14, 20).

When the nucleus begins division the chromatin masses arrange themselves in a spireme (figs. 2, 3) and the linin reticulum can no longer be seen. Perhaps the network has drawn tighter, the threads stretching out to form a framework for the spireme. This stage has been called "close mother skein" (Schaffner). In figure 2 the nucleoli are still present, but they are now without the surrounding clear spaces.

The spireme soon becomes looped with the heads pointing toward the poles. I have not observed any connection between this fact and the fact that the chromosomes are J- and U-shaped. The segmentation of the spireme does not seem to occur regularly near the equator of the nucleus, as would be necessary to make the heads of the chromosome loops identical with those of the spireme loops.

At about this stage the nuclear membrane disappears, as do the nucleoli. There is, of course, variation about the time of disappearance, for the membrane is still present in figure 4, where the granules have split to form a double spireme. This split is very clearly shown in figures 5 and 6. The spireme granules here have segmented to form the chromosomes. Immediately after segmentation the chromosome granules condense and the segments shorten, thus giving the apparently solid character to the chromosomes. In figure 6 the two lower segments have lagged behind the others in condensation.

At this stage or earlier the *anlage* of the spindle should appear, for in the next stage observed the chromosomes were arranged on the bipolar spindle in the metaphase. The origin of the spindle was not observed, however, nor were any traces of a multipolar spindle seen. This may be due to any one of the three causes: the duration of the multipolar spindle may be short; the spindle substance at this stage may not take the stain readily; or the bipolar spindle may have been formed in the manner usual in the cases of higher plants, but with the omission of the multipolar stage. Of these three hypotheses for the absence of the multipolar stage, the third seems, perhaps, the best from the evidence in hand. The probability of the hypothesis decreases when we consider that the central spindle fibers stain more deeply than the traction fibers. No centrosome or centrosphere was seen in these cells, although in one or two cases a massing of protoplasmic granules at the poles of the cells might have been taken on a superficial examination for a centrosphere (figs. 7, 11). It was not difficult to determine, however, that such was not the case, and it seems quite certain that the spindle is formed without the influence of other archoplasmic structures.

In most cells there is no metaphase for the entire chromosome mass, *i. e.*, an equatorial plate, in these cells, but each chromosome passes through the stage without waiting for the others. Figures 7 and 11 are the only approach to such a condition, and even here there is some lack of uniformity in the division of the chromosomes. Figures 8, 9 and 10 show the usual condition of the equatorial plate. Figure 10 shows the longitudinal split of the undivided chromosomes very clearly. This cell was crushed, but the crushing served to bring out the split all the better.

During the metaphase the first signs are seen of the concentration of the cytoplasm at the center of the cell, where the new wall is to be formed, and the consequent vacuolation of the cytoplasm at the poles. (This phenomenon is the usual occurrence in these cells but there are numerous instances where it is only slightly marked.) This concentration seems to aid in the construction of the new cell plate, for the more marked the concentration the more rapid the cell-plate formation.

In regard to the division of the chromosomes nothing unusual was observed. The chromosomes divide and pass to the poles as in most forms. In passing up to the poles the chromosomes usually turn with the short arm of the J toward the center of the spindle. One chromosome seemed to stand out from the rest slightly and was especially marked by its size; this was the long chromosome *m* (figs. 9, 14). Polar views of the anaphase present the best opportunities for counting the chromosomes, but there is much uncertainty even here, owing to the difficulty of getting all of the plate in one section or of tracing it through neighboring sections. Fourteen chromosomes were counted in about a dozen cells, but this, of course, is insufficient evidence on which to base a decision.

Arrived at the poles the chromosomes fuse end to end and then form a loose daughter "skein." This "skein" becomes a close one and the chromatin forms a dense mass at the poles. The remainder of the nuclear reconstruction consists in the formation of the membrane, the distribution of the chromatin granules in the nuclei, the appearance of the linin network and the formation of new nucleoli. It is a general rule that the nucleoli arise on the side of the cell nearest the new cell wall.

While the reconstruction of the nuclei has been in progress, several changes have occurred in the spindle and the cytoplasm. As soon as the concentration of the cytoplasm is complete the spindle broadens out somewhat. Figure 23 shows a maximum bulging, while figure 22 is perhaps a minimum. Figure 22 shows an unusual phenomenon in the process; the majority of the central spindle fibers (only the central fibers now remain) seem to have become free at their polar ends and to have shortened towards the center, staining very darkly in this region. The threads disappear as soon as the cell walls are formed. It is difficult to determine what the bulging out of the spindle and the concentration of the threads and cytoplasm signify, but it seems probable that the threads contain some substance useful in the construction of the new cell wall. This suggestion is in line with the work of Strasburger (4) and Haberlandt (5), who have discussed this phenomenon of the spindle in detail.

The rate at which these processes occur varies. One may find a nuclear membrane before the cell plate has started (fig. 20), or he may find the cell plate well started while the chromatin is still in the loose daughter "skein" (fig. 19).

GENERAL CONSIDERATIONS.

Achromatin and Archoplasm.—In regard to the origin of the spindle Schaffner concludes that, in root-tips of the onion and of *Sagittaria*, at least, the multipolar spindle is due either to pathological causes or to "improper manipulation in preparing the sections," and that a bipolar spindle is formed not by the transformation of a multipolar stage but under the influence of a centrosome and centrosphere as commonly described for animals. As previously stated, I find no evidence whatever for concluding that such archoplasmic structures are present.

Although no traces of a multipolar spindle have been seen here, it is not necessary to assume that a centrosome is present to guide the formation of the bipolar spindle, as the fibers themselves may possess sufficient directive energy to bring about the bipolar form.

Individuality.—A single bit of evidence was found in support of the theory of individuality of the chromosomes in vegetative cells. In several of the cells there is an unusually long chromosome, *m*, in general dividing before the others in the cell. Although this meager bit of evidence is by no means conclusive, it points toward the view that while the cell is the unit of structure the chromosome is the unit of potentiality, and that the chromosomes themselves may all differ in structure and, if in structure, also in potentiality.

An interesting problem concerning these root-tip cells is the relation of the cells to the entire tissue and the cytological processes of later stages of embryonic growth. Material for this study is not at hand at this time, but I hope to be able to trace out these processes at some subsequent period.

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NOTE.

The drawings of the *Podophyllum* root-tips were all made with the aid of a camera lucida (B. & L.) A C. Reichert 1/12 objective was used and with it a B. & L. ½-inch ocular for the larger figures and a ¾-inch for the smaller, making a magnification of 2466 and 2000 diameters, respectively.

Figures 9, 13, 14, 15, 16, 18, 20, 22, 23, 24, were made from material stained with the Flemming three-color method. The others were made from sections stained with the iron-hæmatoxylin method.

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KOEBERLINIA SPINOSA ZUCC.: AN ECOLOGICAL STUDY OF THE ANATOMY OF THE STEM AND SOME OTHER PARTS, ... *Miriam Sheldon.*

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KOEBERLINIA SPINOSA ZUCC.:

AN ECOLOGICAL STUDY OF THE ANATOMY OF THE STEM AND SOME OTHER PARTS.

BY MIRIAM SHELDON.

Plates XVII to XXV.

INTRODUCTION.

SOME plant forms are peculiar and striking. Those of the desert are particularly individual, many being even grotesque in their chance variations. The choice of one of these plants for study was suggested by Professor Stevens, of the Botany Department of the University of Kansas. Accordingly, after sectioning and examining about fifty or sixty plants, I selected and studied three more carefully. Of these the subject of this sketch is perhaps the most interesting.

The material for this study was obtained in the summer of 1908. In July of that year collections of about sixty or seventy different species were made by Mr. L. M. Peace, of the University of Kansas laboratories. These were taken from the region around about Tucson, Ariz., representatives of some species being taken from several habitats, as from mesa, wash, irrigating ditch or hill top. As the short summer season of rains had just begun some of the plants were obtainable before the leaves had appeared. Specimens were, of course, also taken after the leaves came out. The jars with their preserving fluid (two per cent formalin) were taken into the field, and the plants put into these as soon as collected. In many instances the whole plant was secured, one jar containing the root, stem, leaves and flower or fruit of the same plant. It will be seen that this collection is particularly valuable because of the great care taken in obtaining it. Many thanks are due Mr. Peace on this account, as well as for numerous verbal explanations and descriptions of the desert, the vegetation and the individual plants.

The literature dealing with the desert plants is, as is well known, somewhat meager. So far very little more than a description or a mere mention of *Koeberlinia* has been found. Gray describes it in his Plantæ Wrightianæ, and places it with the Rutaceæ. Engelmann mentions it twice in his works: once in his review of the Wislizenus plants and once as erroneously numbered by Emory among his Cactaceæ of the Southwest. Bentham and Hooker describe it under the family Simarubaceæ. The Ailanthus, or "Tree of Heaven," is perhaps the most familiar representative of this family with us northern dwellers among mesophytic forms. John Charles Van Dyke alludes to the "crucifixion thorn" in "The Desert." He says he has met with it in several localities although it is reported as "very scarce." Several travelers in Mexico and the Southwest have made collections of this plant or have reported it. Prof. Charles Bessey, of the University of Nebraska, in the "Burro Thorn" (*Holocantha emoryi*) finds a plant of great interest, if not one wholly as attractive morphologically, if one may judge by the brief account he was able to give for lack of the "oft promised material."

A description of the plant as a whole has not been found. We do not know that anyone has ever had the hardihood to dig up a root. It is said to make an impenetrable barrier, so that a plant three feet high is of such dense growth that the main stem is hardly to be seen. Among the earlier collectors of the plant might be mentioned Chas. Wright, Dr. Josiah Gregg, Gen. Wm. H. Emory and Dr. N. Wislizenus. The plant is sometimes called "Junco." It seems as the northern border of Mexico is approached the individual plants become more stunted and less numerous than farther south. The plant is thus described by Sargent:

"Leaves, not more than one inch long. Flowers, appearing in May and June, about one-fourth inch in diameter. A bushy tree, rarely twenty to twenty-five feet high, with a short, stout trunk sometimes six to eight feet long and a foot in diameter; more often a low-branching shrub forming impenetrable thickets, often of considerable extent. Wood very hard, heavy, close-grained, dark brown somewhat streaked with orange;

becomes almost black on exposure, with thin yellow or nearly white sapwood of twelve to fifteen layers of annual growth. Distribution: Dry gravelly mesas and foothills, valley of the Lower Rio Grande, Texas, westward to southern through northern Mexico."

The four or five plants seen by Mr. Peace were of various sizes, the largest—the one from which the specimens were taken—being about three feet wide and very compact in growth. The branches were pale green in color, no leaves, the flowers whitish to cream color. This was about three miles southwest of Tucson.

As far as observed every branch is a thorn, some of them a little blunt at the end and not tipped with the brownish needle-like point. The thorns vary from 1.5 cm. to 7 cm. in length, being from 1 mm. to 4 mm. in diameter at the base. The largest stem obtainable for study was about 4.5 mm. in diameter, and was probably five or six years old, possibly more. To all appearances the bark is smooth, but microscopically it is somewhat rough, the roughness due to the dome-shaped projections which occur over the stomatal chambers. The flowers are borne along the sides of very small sharp thorns. They have the appearance of being in a raceme—an umbel-like raceme, some authors call it. The leaves, said to be scalelike, are soon dropped.

INVESTIGATION.

The study of the desert plants was taken up in February, 1909, in connection with other graduate work at the University of Kansas, and continued until the middle of August of that year.

The methods employed in pursuance of this study were various. The chlor-zinc-iodide treatment of sections fresh from the formalin or paraffin, or softened from the dried state, proved on the whole the most satisfactory.

All the figures, except a few of the flower and some diagrammatic ones, were made by the aid of the camera lucida, the projection lantern or the photographic camera.

Stem.—The stem as a whole shows some interesting features in cross section, of which the thick epidermis, deeply sunken stomata, the deep palisade tissue, compact wood and small water tubes are not the least striking.

The *tissues* might be taken in their order, beginning with the innermost one. It has been observed that no generalization can be made in regard to the structure of these desert plants, each one having its own peculiar way of getting on.

The *pith* occupies a sort of triangular area. The cells are comparatively large (see table), are heavily lignified, deeply pitted, stored with starchy material, and possessed of—in almost every case—a small crystal having the form of the calcium oxalate crystal. In the younger flower branch we find cells with thick walls, also, but retaining their rounded shape, pitted, and plentifully surrounded with air spaces. No food material was observed stored in this region. In the older stem elongated pit cells next the trachial tubes are densely filled with material that stains blue with c. z. i. This has a fine granular appearance (fig. 2, plate XX).

The *medullary rays* are conspicuously broad in cross section, many being five cells wide. The cells are comparatively large. They have the ordinary cylindrical shape with thick lignified and pitted walls. (Figs. 3 and 5, plate XIX.) Intercellular spaces are frequent. Most of the cells are full of non-nitrogenous material, while a few narrow and elongated ones appear adapted for quick conduction. Those between the phloëm strands show the characteristic proteid reaction with c. z. i. and have the usual unpitted walls. Crystals are often found in these cells.

The *xylem* makes up a great part of the stem. The wood fibers cannot be said to be very numerous. They have the usual shape and are rather short. (See table.) The fiber-tracheids are found quite plentifully and correspond closely to the wood fiber. The bordered pits, however, are very numerous, there being at least 200 to a tracheid. (Fig. 15, plate XX.) The pits are small. The spiral tracheids have the single and double spiral threads. These vessels are decidedly small. The tracheids are of three kinds and vary in length and diameter. (See table of measurements.) The tracheal tubes have many small bordered pits and have thickenings in ridges in the walls. The whole tube is divided at more or less regular intervals, as from 0.6 to 0.27 mm., by thick rings. Upon investigation these may sometimes be seen to be in the plane of union of neighboring tubes, the walls being so completely fused as to obliterate all trace of joining. It seems that these rings are really the borders of an aperture in the ends of tube elements, occurring in the earliest laying down of the tissue. They were observed in the last vessels laid down before collecting in the midst of the rainy season of 1908. (See figs. 5 and 6, plate XX.) These pitted vessels, often with ragged inner thickenings (fig. 6), are found from the spiral vessels next the pith to the latest growth. They are also found in the young thorn which bears the flowers. The end of this division of the tracheal tube is often very much elongated and gradually tapering (figs. 3, 4, 9). Sometimes the long tapering is omitted and we have a peculiar cell ending as in figures 6*a* and 7. These elements sometimes taper at both ends, but frequently and abruptly in horizontal base. (Fig. 3.)

Besides the tube elements just described, there are the more or less rectangular tracheids that join their neighbors above or below by horizontal or oblique walls. (Fig. 13.)

No means to be had will give an exact account of the age of the stem. This is true of most of the perennials of the desert, we believe. Upon projecting upon the screen by means of the lantern, a cross section of the older stem showed traces of five or six seasons' growth, a slight increase in the size and number of the vessels being noticeable in each successive yearly growth as well as a somewhat greater compactness of growth in the wood itself. Probably for the year 1907 a new set of vessels has been formed. (Fig. 1, plate XVIII.) Outside of these is a second set of larger and unquestionably new water vessels laid down at the beginning of the rainy season of 1908. The width of an annual ring varies somewhat, but on the whole has an average of about 0.2 mm. The entire radial measurement of the wood from pith to phloëm is about 1.5 mm. This would make the stem about seven and a half years old.

The *Phloëm* region shows the usual storage of nitrogenous materials in the sieve and companion cell portion and in the parenchyma. The elements of the sieve vessels are rather long (see table) and full of fine granular material. The sieve plates are heavy, with very minute perforations on the sides. The phloëm parenchyma in my material occurs in a series of five parts, each being about three cells wide. (Fig. 1, plate XXI.)

The *stone cells* and *bast* make a hard, rigid cylinder around this more delicate portion, the stone cells occurring between the bundles of bast and extending around them.

The sclerenchymatous or stone cells are of various shapes: some are squarish, some oblong, and some so elongated as to be confused with the bast as far as shape goes, but possessing the deeply pitted characteristic of the stone cell. This zone occupied by the stone cells is broad. Sometimes the cells are found in the region of the palisade cells, in scattered patches, or in many cases filling up air cavities below the stomatal chamber. (Fig. 1, plate XXIII.)

The bast appears to be of twofold character—the ordinary long, tapering cells, united by a long splicing, then another kind, shorter and tapering abruptly at one end, while the other end, rather blunt, fits securely into the socket made by the two cells below. (Figs. 8, 9, 10, plate XXI.) These fibers occur in the regular bundles, but they also make a sort of inner bundle, we think; at least, in all the cases so far examined they appear to occupy that position. They may make a sort of inner supporting shaft to the whole group. When separated from the long fibers a bundle of them looks like a barbed shaft.

The *spongy parenchyma* tissue takes up the inner collenchyma region. These are about five or six cells deep radially. The walls of some of the parenchyma of the innermost portion are heavily lignified. Neighboring cells have not so changed materially, but the cellulose wall is thicker in many cases. The walls in all the sponge are about twice as thick as those of the palisade region. The spongy cells are spherical, cuboidal or ovoid in shape, and about twice the diameter of the palisade cells. The numerous and large intercellular spaces in this region are conspicuous. There are besides whole rows of open spaces, seen in either cross- or longi-sections. (Fig. 9, plate XXII.) This will be taken up in a later paragraph, however.

The *palisade cells* lie in characteristic position, two or three deep radially. They are thin walled, cylindrical in shape, with some, but rather small, intercellular spaces. The chloroplasts are of goodly size, and show a deep blue in treating with c. z. i. In this region also are to be found very large aerating chambers, ovoid in shape, connecting directly with the stomatal chamber above, and thence with the outer world. These are not quite so numerous as the smaller cavities mentioned in the sponge. (Figs. 3, 4, plate XXII.)

The *epidermis* is remarkable. The cuticle itself is very heavy, it being 0.015 mm. in thickness in the old stem. The whole epidermis as found in the older stem measures from 0.075 mm. to 0.105 mm. There is but one row of epidermis cells. These are elongated radially, and in the younger parts of the plant are of thin cellulose walls. In the older parts the walls become very much thickened, so much so that in time only a conical space at the bottom represents the cell cavity. (Figs. 4, 5, plate XXII.) At intervals these picket-like cells give way to large cavities, which they surround and protect by a slight modification at the outer extremity, a curving upward and inward, thus making a little dome of from eight to a dozen cell tips. (Figs. 3, 1, plate XXIII.) These, not entirely closing the cavity, leave an aperture allowing of communication between the outer world and the stomatal apparatus within and thence farther beyond to inner tissues. (Fig. 8, plate XXII.) The details of this arrangement, although seemingly complex, are actually simple. The stoma lies at the base of the epidermal air chamber; slight projections of the walls of the guard cells make a shallow stomatal chamber immediately above, and like ones make one below. Beyond the lower lies the large ovoid cavity referred to in the palisade tissue. (Figs. 8, 9, plate XXII, fig. 11, plate XXIII; and for measurements, see table, p. 7.) A curious little Phycomycete makes its home in the outside stomatal cavities. It occurs in a majority of the stem stomata. (Fig. 7, plate XXII.) There are about 150 stomata to a square millimeter. (Fig. 2, plate XXIII.) In the younger stem a tissue for water storage occurs just outside the pericycle. Sometimes this appears to be represented by a single cell only. (Figs. 8, 9, 10, plate XXIII.) The region of spongy parenchyma here stains deep blue with c. z. i., while the palisade cells remain yellowish.

Flower.—The flower, cream color to yellow, shows the four-parted arrangement—four very short triangular sepals, greenish in color; four long, blunt, prominently veined petals, enclosing eight stamens, which show an inequality in length of filament. The anthers are elongate-ovoid, and open on the side. They are attached to the filament at about one-fourth the distance from the base. The filaments are stout and tapering upward. The superior ovary is globose in shape, tapering above into a pillarlike style, which in turn tapers slightly at the apex to form the stigma, which is a plain surface surrounding a circular orifice.

Upon sectioning the ovary longitudinally the numerous ovules are noticed in longi-section; they appear hanging down from the central placenta. In cross section two cells are seen, and in some parts a suggestion of two side partitions. The ovary wall is cutinized heavily without and within, insuring protection for the ovules against the intense aridity of the desert atmosphere. The mesophyll of the ovary is well supplied with chorophyll bodies and contains numerous mucilage cells, thus assisting in the provision for intensest drought. A resinous gum is found in the seed vessel surrounding the ovules and the vascular bundles in the placenta. (Figs. 1, 2, 3, 4, plate XXIV.) The resinous gum is not found elsewhere.

The contents of the cells of the stomata of the inner wall of the seed vessel stain a deep blue with c. z. i., showing that the guard cells here are living and filled with non-nitrogenous material.

The mucilage cells finally break down, thus forming large mucilage reservoirs. (Figs. 8, 7, 5, plate XXIV.)

CONCLUSION.

Koeberlinia is what Clements would call a stem xerophyte. The low stature of the plant, its compact habit of growth and the heavily cutinized surface everywhere, reduces evaporation to a minimum. The dead-air spaces furnished by the outer stomatal chambers also contribute toward this end. A supply of moisture is insured for the more strongly growing parts by the storage of water in special reservoirs and by the presence of mucilage in the seed vessel. The resinous gum aids in conserving moisture. Greater strength is secured, perhaps, through the peculiar splicing of the large tracheids. The stone cells, with their firm adherence to the bast fibers, also give strength. The air spaces in epidermis, palisade tissue, sponge, medullary rays and pith insure a goodly supply of CO_2 without much evaporation. These points might be summed up thus:

Evaporation minimized by:

1. Dispensing with leaves.
2. Heavy cutinization on all exposed surfaces.
3. Dead-air spaces (outer stomatal chambers).
4. Low stature.
5. Compact growth.
6. Resinous gum surrounding tender growths.

Moisture supply provided for by:

1. Special reservoirs for water storage.
2. Mucilage in cells in seed vessel.
3. Tracheal elements.
4. Presence of resinous gum.

Strength attained by:

1. Extreme lignification.
2. Long splicing of bast.
3. Long splicing of large tracheids.
4. Heavy zone of stone cells firmly adhering to bast.

Supply of air provided for by intercellular spaces in:

Epidermis.
Palisade.
Sponge.
Medullary ray.
Pith.

On the whole, this plant presents a wonderful array of "aids" to getting on in the desert. No other plant examined showed so thick an epidermis and such an aerating system. A few were almost leafless, a few had a heavy epidermis, some were strongly lignified, others showed resinous secretions. Almost all had larger water-conducting vessels. With all the adaptations that this plant had it seemed strange that it was so rare, but upon investigation we find that by abortion the many seeds are reduced to one, two or three to a berry. We have not yet found out whether the berry is eaten by animals or not.

Tables of measurement, rainfall and evaporation are presented for reference; also, a very superficial table giving some facts in regard to a few other desert plants. I am indebted to Mr. Peace for the tables on rainfall and evaporation. He has also kindly furnished the two photographs as well as much valuable information. Thanks are due to Doctor Trelease, Doctor Land and Doctor Spalding, for kindness in answering inquiries. I also wish to thank Doctor Billings for suggestions, and Professor Stevens especially for ever-ready assistance. It is a pleasure here to express gratitude to Doctor MacDougal for freely granting the facilities of the desert laboratory while the materials were being collected.

TABLE OF MEASUREMENTS.

	Structure.	*Length, mm.*		*Width, mm.*	
1.	Mid pith cell	0.03 to	0.045	0.03 to	0.075
2.	Marginal pith cell	.045	.075	.01	.015
3.	Medullary ray cell	.05	.075	.012	.014
4.	Wood fiber	.....	.24	.....	......
5.	Fiber tracheid	.....	.25	.....	.015
6.	Tracheal tubes	.06	.27	.01	.03
7.	Tracheids	.....	.114	.015	.025
8.	Sieve cell	.03	.25	.....	.015
9.	Phloem parenchyma	.022	.12	.....	.015
10.	Stone cell	.05	.12	.015	.06
11.	Bast (long)	.06	.15	.....	.013
12.	Bast (short)	.015	.03	.....	.007
13.	Spongy parenchyma	.015	.03	.....	.02
14.	Palisade cells	.....	.....	.01	.012
15.	Epidermis, older stem	.....	.....	.075	.105
16.	Cutinized portion epidermis, old stem	.....	.....	.....	.075
17.	Epidermis flower branch	.....	.....	.....	.06
18.	Cutinized portion epidermis, flower stem	.....	.....	.....	.013
19.	Epidermis-ovary, outer	.....	.....	.03	.065
20.	Cutinized portion epidermis-ovary, outer	.....	.....	.01	.015
21.	Epidermis-ovary, inner	.....	.....	.02	.045
22.	Cutinized portion epidermis-ovary, inner	.....	.....	.....	.01
23.	Epidermis of anther	.....	.....	.....	.02
24.	Cutinized portion epidermis, antner	.....	.....	.....	.0019
25.	Epidermis of petal, outer	.....	.....	.....	.02
26.	Cutinized portion epidermis-petal, outer	.....	.....	.....	.0019
27.	Epidermis petal, inner	.....	.....	.....	.015
28.	Cutinized portion epidermis-petal, inner	.....	.....	.....	.0019
29.	Upper stomatal space	.....	.12	.....	.04
30.	Lower stomatal space	.....	.06	.....	.03
31.	Outer stomatal aperture	.....	.....	.....	.008
32.	Inner stomatal aperture	.....	.....	.....	.015
33.	Air space in sponge	.03	.045	.025	.032
34.	Mucilage cells	.....	.....	.....	.0325
35.	Mucilage reservoirs	.....	.....	.06	.15
36.	Water storage cells	.03	.06	.03	.045
37.	Resinous gum cells	.03	.092	.015	.02
38.	Intercellular space, pith	.....	.....	.007	.015
39.	Intercellular space, sponge	.....	.....	.003	.015

RAINFALL NEAR TUCSON.

Jan. 3	0.62 inch.	Apr. 23	0.11 inch.
“ 15	.05 “	May 3	.05 “
“ 23	trace.	“ 23	.03 “
“ 30	“	July 5	trace.
Feb. 3	0.29 inch.	“ 7	0.04 inch.
“ 4	.57 “	“ 10	trace.
“ 7	trace.	“ 13	“
“ 10	0.16 inch.	“ 15	0.80 inch.
“ 11	.47* “	“ 16	1.00 “
“ 13	.24† “	“ 17	2.6 “
“ 22	.15 “	“ 19	.01 “
Mar. 4		“ 23	.61 “
“ 19	trace.	“ 25	1.81 “
“ 20	0.38 inch.	“ 27	.02 “
“ 26	.03 “	“ 28	.42 “
“ 27	.01 “	Aug. 2	.42 “

* With snow. † With sleet and snow.

TEMPERATURE AT THE DESERT LABORATORY.

	Lowest.	*Highest.*		*Lowest.*	*Highest.*
July 6	77° F.	99° F.	July 18	65° F.	74° F.
“ 7	77	103	“ 19	68	87
“ 8	74	99	“ 20	75	95
“ 9	78	90	“ 21	75	99
“ 10	78	95	“ 22	75	94
“ 11	74	101	“ 23	62	92
“ 13	71	100	“ 24	65	90
“ 15	67	97	“ 25	72	91
“ 16	69	88	“ 26	62	92
“ 17	64	82	“ 27	69	84

RAINFALL OF TUCSON VICINITY.

	1904.	1905.	1906.	1907.	1908.
January	....	1.91	0.60	2.47	0.67
February	....	4.11	1.26	0.08	1.89
March	....	4.27	0.31	0.41	0.52
April	....	3.11	0.34	0.00	0.11
May	1.29 ?	0.03	0.02	0.45	0.08
June	0.04	0.24	0.00	0.00	0.00
July	2.07	1.47	2.07	4.67	5.73
August	3.00	0.47	1.16	3.66	*0.42
September	0.61	2.24	0.28	0.28	....
October	0.07	0.05	0.01	0.95	....
November	0.05	4.52	0.66	0.74	....
December	1.07	0.90	4.40	0.00	....
Totals	8.20	23.31	11.10	13.72	9.42

* To August 2.

From July 5 to July 31 there were twelve days upon which rain fell. There was rain during one day of each of the months of April, May and June. (These statements apply only to the year 1908.)

WEEKLY AVERAGES OF EVAPORATION,

In cubic centimeters, from free surfaces at a height of 25 centimeters above the ground.

	June.	July.	August.	September.
Tuscon	338	228	212	278
St. Louis	112	157	140	137
Lincoln	96	90	113	144
Chicago	93	95	109	95
New York	...	48	63	85

Temperatures, July 5, 1908, to August 2, 1908: Lowest, 62° F.; highest, 103° F.

NAME.	Epi.	Pith.	Water tubes mm. × sec.	Wood.	An. ring.	Med. ray.	Bast.	Air space.	Storage.	
									Food.	Water.
Cassia covesii...........	Thin.	0.0015	0.03 even scat.	Dense.	'08 only.	1 cell wide.	Bundle.	In pith.	Rays.	
Celtis reticulata.........		0.007	0.045	Dense in patches.	0.45 mm. '07; prominent.	?	Narrow ring.		Pith.	
Cercidium torreyana.....		0.003	0.037	Dense mod.	0.07 mm. few; '06.	1 cell wide.	Bundle.		Pith.	Epedemics.
Covillia tridentata.......		0.006	0.05 to 0.015	Dense.	Slightly marked.		Heavy band.		Rays tracheids and pith.	Epidermis.
Encelia farinosa........		0.0015	0.045	Trach. 0.001	0.27 mm.; plain.		Bundle.		Few pith.	
Fouquieria splendens....	Cells many.	0.0015	0.04	Fibers.				Frequent pith.		?
Jatropha................		0.0015	0.06	Trach. only 0.05	0.6	1 cell wide.		In pith.	Rays—pith.	?
Koeberlinia spinosa......	0.09 mm.	0.007	0.004 to 0.015	Dense fib.—trach.	0.21 mm. '07; prom.	2 to 5 cells wide.	Bundle.	Bark.	Rays—pith.	
Krameria................	0.029	0.0025	0.03	Dense fib.—trach.	0.38, '07—0.6	1 cell wide.		Minute.	Pith.	
Phoradendron...........	0.022	0.003	0.03 to 0.015			Immense.			Every-where.	
Parkinsonia microphylla,	0.007		0.06 to 0.09	Trach. 0.014	0.45 mm.; 9 yrs.	1-3 cells wide.			Pith.	
Prosopis velutina........		0.005	0.07 to 0.015	Heavy in patches.	0.3 (?)	1 cell wide.			Tracheids.	
Sambucus...............	Sev. celled.	0.0015	0.037	Few fib. trach.	'07—0.37 mm.	1-3 broad.	Bundles.	Few large.	Trach. rays.	
Schinus mollis...........			0.03	Trachs. mostly.		Row large.	Little.	Few large.	Rays.	Bark.
Negundo sp.............		0.0015	0.045 to 0.015	Tracheids.	0.3 to 0.15 mm.	1 cell wide.	In bundles.		Rays and pith margins.	

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CONTENTS:

A Case of Absolute Tone Memory, ... *Archibald Hogg.*

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A CASE OF ABSOLUTE TONE MEMORY.

BY ARCHIBALD HOGG.

EXTRAORDINARY forms of consciousness are necessarily few, otherwise they would not be extraordinary. They are usually worthy of study and report directly by reason of inherent interest and indirectly through the light they throw on mental process in general. Among the exceptional forms of memory activity we find in hearing what is called by musicians "recollection of absolute pitch," by psychologists "absolute tone memory." A striking instance of the possession of this faculty led the writer, assisted by a friend[1] who is a skillful amateur violinist, to make the two tests herewith reported.

The subject[2] is a boy thirteen years of age, a quiet, gentle lad, imaginative, introspective, fond of his music and of long walks, and is perhaps less vigorous than the average child of the same age.

He gave early evidence that he possessed unusual musical gifts. One night when he was about four years old, and while lying in bed, he listened to the playing of a wedding march at a marriage ceremony in a neighbor's house. The next morning he climbed on the piano stool at home and reproduced the march—but in a simpler way. At the age of six his musical education began with lessons on the piano, and it has continued ever since except when interrupted by the vacations and illnesses incident to childhood. His possession of absolute tone memory was so strikingly emphasized as to attract attention one day about three years ago, when he remarked to an older brother who had just tuned a cello that the pitch of the instrument differed from that of a few days before—an observation that was verified by appeal to the piano. Since then the boy has been tested, usually for amusement or out of curiosity, some five or six times, but without any records being kept. Composition comes easy to him and he has composed not a few melodious pieces during the last four or five years.

---

[1] Mr. A. K. Hubbard, assistant professor of civil engineering in the University at the time.

[2] The boy is the son of a professor in our University. Both parents are musical. One older brother plays the cello, another plays violin. Two younger children cannot be characterized with much certainty yet with respect to musical ability.

The notes given in the tests and the observer's judgment are indicated in accordance with a quite simple plan. The notes from and including middle C to its octave above are left unmarked. A tone in the next higher octave is indicated by a single accent mark above the letter, in the second higher by two accents placed above, and so on; similarly with the lower octaves, except that the accent marks are placed below the letter in such instances. The usual symbols for sharp and flat are used after the prescribed fashion.

The note or notes struck are placed first in the record and are followed immediately by the observer's judgment. In both tests the observer himself was seated with back turned at a distance of about eight feet from the instrument and was looking away from it. In other and unrecorded tests at home he has been sent at different times to various places about the house within hearing distance of the piano. The results of the unrecorded tests have been practically the same, as conversation with people present on such occasions has revealed. The uniformity of testimony regarding these unrecorded tests is the reason why more tests were not made by the present experimenters.

The first test was made on the observer's piano in April of this year. The results are given in table I.

Several times the observer was asked not to name the notes but to come to the piano and point them out without striking the keys. It was doubtless an unnecessary precaution.

A few miscellaneous tests were next made. The observer was asked to reproduce, either by whistling or singing, certain notes that were named, and thereupon sang or whistled in correct pitch, as shown by the piano, the following notes,

f#′, g#, c#͵, b♭, f, b‴ a″, d.

Following that a simple tune was played on the violin and the key asked for. It was promptly and correctly given. The

TABLE I.

Stimulus.	Judgment.	Stimulus.	Judgment.
C	C	$\mathrm{D}_{\prime}$	$\mathrm{D}_{\prime}$
E	E	$\mathrm{F\,B}b$	$\mathrm{F\,B}b$
A'''	A'''	$\mathrm{B}_{\prime}\mathrm{G}$	$\mathrm{B}_{\prime}\mathrm{G}$
D''	D''	G G♯	A*b* A
$\mathrm{B}_{\prime\prime\prime}$	$\mathrm{B}_{\prime\prime\prime}$	$\mathrm{E}_{\prime\prime\prime}\mathrm{G}_{\prime\prime\prime}$	———
G'	G'	$\mathrm{B}'''\,\mathrm{F}'''$	$\mathrm{B}'''\,\mathrm{F}'''$
$\mathrm{F}_{\prime\prime\prime}$	$\mathrm{F}_{\prime\prime\prime}$	$\mathrm{G}_{\prime\prime}\,\mathrm{B}_{\prime\prime}\,\mathrm{D}_{\prime}\,\mathrm{G}_{\prime}$	$\mathrm{G}_{\prime\prime}\,\mathrm{B}_{\prime\prime}\,\mathrm{D}_{\prime}\,\mathrm{G}_{\prime}$
B'''	B'''	$\mathrm{E}b_{\prime\prime}\,\mathrm{G}_{\prime\prime}\,\mathrm{B}b_{\prime}\,\mathrm{D}_{\prime}$	$\mathrm{E}b_{\prime\prime}\,\mathrm{G}_{\prime\prime}\,\mathrm{B}b_{\prime}\,\mathrm{D}_{\prime}$
$\mathrm{D}\sharp_{\prime\prime\prime}$	$\mathrm{D}\sharp_{\prime\prime\prime}$	C F♯	C F♯
G'''	G'''	$\mathrm{E}_{\prime\prime\prime}\,\mathrm{G}'''$	$\mathrm{E}_{\prime\prime\prime}\mathrm{G}'''$
$\mathrm{A}b'$	$\mathrm{A}b'$	$\mathrm{D}_{\prime}\,\mathrm{C}\sharp$	$\mathrm{D}_{\prime}\,\mathrm{C}\sharp$

experimenters having an idea as to the method of recognition, parts of three or four tunes were played, care being taken not to stop on the key note. The recognition was again prompt and accurate. Being questioned, the observer said his judgment in the first instance was determined by following the general rule that a simple melody ends with the key note. In the subsequent selections the judgment was determined by the sequence of the notes.

Then a high note on the violin between $b\flat''$ and b'' was struck. When asked the pitch the observer mentioned b'', and upon being told it was not exactly that he named $b\flat''$.

Next, several double stops were given on the violin, one note being a shade off the key in each case. The note that was in error and the direction in which it should be changed were correctly given. The observer was now asked to direct the operation of tuning the A string of the violin until it corresponded with his own piano. The result, as shown by the piano, proved that the judgment was slightly in error in the flat direction. The same test on the D string gave a correct judgment. Practice with the A string doubtless helped here.

Lastly, the opening notes of a piece were sung. They were named correctly by the observer, as appeal to the piano demonstrated. He is ignorant of fingering of the violin.

The second test was made one afternoon about a month later with the piano used twice a week by the observer when he takes his music lesson. The instrument is tuned to international pitch and is lower than his own. He said it sounded flat. The results are in table II.

TABLE II.

Stimulus.	Judgment.	Stimulus.	Judgment.
C♯	C	G$'''$	G$'''$
G$_{\prime\prime\prime}$	G$_{\prime\prime\prime}$	A♭$'$	G$'$
A$'''$	A$'''$	D$_{\prime}$	D$_{\prime}$
D$''$	D$''$	A♭$'$	G$'$
B♭$_{\prime\prime\prime}$	B♭$_{\prime\prime\prime}$	G♯$'''$	G$'''$
G$_{\prime}$	G$_{\prime}$	F B♭	E A
B♭	B♭	B♭$_{\prime}$ G	A♯$_{\prime}$ F♯
D♯$'''$	D$'''$	C F♯	B F
F♯$'''$	F$'''$	G$_{\prime\prime}$ B$_{\prime\prime}$ D$_{\prime}$ G$_{\prime}$	G$_{\prime\prime}$ B$_{\prime\prime}$ D$_{\prime}$ G$_{\prime}$
F$_{\prime\prime\prime}$	F$_{\prime\prime\prime}$	G♯$''$ B♯$''$ D♯$'''$ G♯$'''$	G$''$ B$''$ D$'''$
B$'''$	B$'''$	G$''$ B♭$''$ D$''$ F$'''$	F♯$''$ A$''$ C♯$''$
D♯$_{\prime\prime\prime}$	D$_{\prime\prime\prime}$	E♭ G B♭ D	D F♯ A C

With the first of the errors it occurred to the experimenters that the judgments were being determined exclusively by simple comparison with the image-standards from the home piano—an hypothesis which would have involved uniformity in the errors. Notes a half tone lower in pitch than those really given should have been named.

Later it occurred to us that the observer himself might be trying to correct the difference between the two pianos. That this was usually the case became known from answers to questions asked after the test. The observer arrived at most of his judgments by traveling the following mental highway: The tone was first identified and named by means of the images from his own piano—the instrument on which he daily played and with which his familiarity was great. Having thus identified the tone as nearly as possible (exact correspondence in any instance would be highly improbable), the simple addition of a half tone brought about the judgment announced.

In a few cases direct recall of the tone-images from the teacher's piano rendered any additional mental labor unnecessary to identification.

In closing, a few statements are made by way of addition and partial summary. For our observer the difficulty of identifying a single tone is scarcely harder in one region of the piano scale than another. But there is a decided difference in ease of analysis according as there are high or low complexes of tones. In the third octave below the mental separation of two notes was not attempted, the remark being made, "It's such a jumble, I can't remember," while in the third above the identification was made with accuracy and without a noticeably great amount of concentration. Images from the organs of utterance seemed to play no part whatever in his recall of tones. Sound images apparently furnished exclusively the material used in all the judgments. Upon being questioned as to his method of identification and of reproduction the observer said he "just heard the tones in his head and told in that way." Of a piece of music recently purchased for him he said he had played it off "in that way" before touching a finger to the piano. His introspective competency was greater than was expected.

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THE HACKBERRY PSYLLA, PACHYPSYLLA CELTIDIS-MAMMÆ RILEY.

A STUDY IN COMPARATIVE MORPHOLOGY.

BY H. B. STOUGH.

Plates XXVI to XXXV, and three figures.

(Contribution from Entomological Laboratory, No. 158.)

Submitted in partial fulfillment of the requirements for the degree of Master of Arts.

OWING to their minute size and obscure life habits, the members of the homopterous family Psyllidæ have received comparatively little attention in North America. In the present paper an endeavor will be made to add to our knowledge of this family, using as a type *Pachypsylla celtidis-mammæ* Riley, the same being a study in comparative morphology of mouth parts, thorax, and genitalia, and development of wing venation and wing pattern. The specimens upon which I have based my studies emerged from their galls upon the hackberry trees during October of 1908, at Lawrence, Kan. I wish to thank Prof. S. J. Hunter, upon whose suggestion the problem was taken up, and under whose guidance and counsel the work was carried on, for his interest in my investigations and for his assistance rendered.

In search for literature on the Psyllidæ of North America, and especially that dealing with *Pachypsylla celtidis-mammæ* and its genus, I was impressed with the fact that very little of a definite and final treatment has ever been given to these insects in this country. A few species have been described, a few figured, and the life histories of a number worked out, while keys for the species of only about one genus can be found.

In Europe, on the contrary, the contributions to the knowledge of this family have been numerous and have added greatly to our information on the subject. The first of these contributions was made by Förster, in 1848. He was followed by Flör, Thomson, and Hartig, but not much of an advance was made upon Förster's work until there appeared in 1879 a treatise, "Zur Systematik der Psylliden," by Löw; this, together with other contributions by the same author, has long remained authoritative. The researches of Löw in the taxonomy and biology of the Psyllidæ, together with the anatomical work of Witlaczil, have much simplified the study of this family in Europe.

James Edwards, in "Hemiptera-Homoptera" (1896), treats of four genera of the family, including twenty-eight species of British Psyllidæ, with tables for the separation of the genera and species. He also illustrates these forms in color and gives the typical wing venation of each genus.

Maskel (1889) lists and describes four species of Psyllidæ from New Zealand, giving keys for separating the subfamilies represented in that locality, and figures the larval, pupal and adult stages, and some of their typical anatomical characters. This paper contains more figures of these characters than any other I have been able to find, and was quite useful from that standpoint. This writer also discusses the use and taxonomic importance of the different characters of the family.

Froggatt (1903), in a paper on "Australian Psyllidæ" describes eighteen species, mostly of the two genera *Aphalaria* and *Trioza*. He figures the galls made by three species of the latter genus.

The reasons for the dearth of material in this country may be found in the fact that the family Psyllidæ, like some other little-known groups, being composed of small and inconspicuous insects, has not been largely collected and studied, two or three species excepted. One of these, the pear Psylla, *Psylla pyricola*, is of great economic importance in some localities, and has long been known and its life history carefully worked out. The life histories of these insects are very difficult to determine definitely, and since some of them are gall-formers, the biological side of the work becomes still more complicated. Only about three specialists have ever devoted much time to their study in this country, among whom was C. V. Riley. In an article on "The Psyllidæ of the United States" (1883), he gives a *résumé* of the present knowledge of the family and its principal characters, habits, life history, etc., listing thirteen species. Undoubtedly the most important work published so far is that by the same writer entitled "Notes on North American Psyllidæ" (1884). This paper lists nineteen North American species, distributed among the following genera: *Livia, Aphalara, Psylla, Pachypsylla, Trioza, Calophyla, Rhinopsylla,* and *Ceratopsylla,* the descriptions of three genera and two species being new. The most important part of this work, from the standpoint of the present paper, is that dealing with the new genus *Pachypsylla.* This genus is peculiar to this continent, having no equivalent in Europe, so Riley thinks, and to it belong the hackberry psyllids. Only three species of these are placed in his key. Riley also discusses "hackberry galls," in the *Canadian Entomologist* (1883).

An important contribution to the biology of the subject, especially of the gall-making phase, is an article on psyllid gall-making in the fifth report of the United States Entomological Commission, written by A. S. Packard (1887). This gives keys to three species; descriptions of pupa; key to, and descriptions of, the galls of the following species and varieties of the genus *Pachypsylla: venusta, gemma, asteriscus, umbilicus, mamma, pubescens, globulus, cucurbita,* and *cucurbita var.* To this is added a detailed description of each gall and a condensed general life history of a hackberry psyllid. No mention is made of the stimuli causing the gall-formation. Ashmead (1881) describes the life histories and gall-making habits of these insects, and lists nine species, adding three new ones.

Two papers by Charles W. Mally, entitled, respectively, "Hackberry Psyllidæ Found at Ames, Iowa" (1893), and "Psyllidæ Found at Ames" (1894), give a series of observations on the winter habits and spring egg-laying of *Pachypsylla celtidis-mammæ,* with descriptions of the eggs, larvæ, pupæ, and galls, and record thirty-one species for North America. He describes four new species and figures the early stages and wing venations.

Where mention is made of the galls in the papers that I have mentioned, only the gross structure of the gall is treated. Cook, however, in "Galls and Insects Producing Them" (1903-'04), has made a contribution toward the histology of the psyllid gall; he also discusses mouth parts and ovipositors in their relation to gall-formation, but in common with other investigators was not able to add much to our knowledge of the gall-producing stimuli.

On the mouth parts of Hemiptera, in addition to works of a general nature, I would cite two of importance in throwing light upon the homopterous mouth as seen in the Psyllidæ. These are by Charles L. Marlatt (1898) and Walter J. Meek (1903), and deal with the mouth parts of the cicada. Besides these, such works as those of Sanborn on the Aphididæ (1905), Berlese on Coccidæ (1896), and others, were of use in a comparative study. The best work upon mouth parts of Hemiptera is recorded in the German of Leon (1887), Geise (1883), Wedde (1885), and Heymonds (1899). Dohrn (1865) contributed to the internal anatomy of the Hemiptera, and Witlaczil (1885) worked out the brain, eyes and digestive system.

GENERAL CHARACTERS OF THE FAMILY PSYLLIDÆ.

The Psyllidæ were formerly classified with the Aphididæ, to which they are closely related, and are still sometimes known as "the jumping plant lice." These insects are from one-eighth to one-fifth of an inch long and in general appearance may be likened to a minute cicada. Their principal characters follow: Hind legs developed for jumping; antennæ nine- or ten-segmented (in life in constant vibration), last segment bearing two short spines; tarsi two-segmented; mouth parts suctorial; wing venation comparatively simple. Some of the species are of economic interest, being injurious through their feeding habits. A number form galls, notably upon hackberry. A few species secrete "honey dew."

According to Mally (1894) there are thirty-nine species and varieties in North America. Only nine species are to be found in the collection of the University of Kansas, four of these having been taken in Kansas. So far, not many fossil insects of this family are known. Scudder lists in "Tertiary Insects of America" (1890) only two species, *Necropsylla rigida* and *Catopsylla prima*, the latter being of interest, as its wing venation resembles more closely that of Riley's genus *Pachypsylla* than of any other.

The species taken for study belongs to this last genus, *Pachypsylla*. The namer, C. V. Riley, says of it: "There is no genus among those characterized by Dr. Fr. Löw with which

Pachypsylla can properly be compared. In the convexity of the body it greatly surpasses *Psylla,* from which it is at once distinguished by the vertical and rugosepunctate head, the quadrate vertex, the short frontal cones, the less filiform and stout antennæ." This species was first listed for Kansas by Tucker in 1907.

The coloration of *Pachypsylla* has been well described by Riley. The general color is dark brown, with the abdomen showing pinkish shades along the edges of each segment. The wing pattern is dark brown, and the ocelli are red.

This insect is quite short bodied; the sexes are easily distinguished, as in all representatives of the family, the end of the abdomen being pointed in the female but blunt and appendage-bearing in the male. The total length of body averages, for the male, 3.2 mm., and for the female, 3.6 mm.

HEAD.

The head is carried in such a position relative to the remainder of the body that the epicranium is in an almost vertical position (*34*-4),* the frontal cones pointing downward, with the outer face of the frons in a horizontal position, its distal end projecting caudad. Viewed from the front, the head corresponds roughly, in general shape, to a right triangle, truncate at the vertex, the posterior edge of the epicranium lying on the base of this triangle, and a point somewhat beyond the frontal cones representing the vertex (*28*-4). The whole head is rather flat, thin, rectangular, and boxlike, the open side of the box being the caudal side (*28*-1), against and into which opening fit the anterior part of the prosternum, the procoxæ and the mouth parts.

The following parts and regions of the head, excluding the frons and clypeus, which will be described under "mouth parts," are to be found: epicranium, genæ, frontal cones, antennal sockets, compound eyes, and ocelli.

The epicranium forms the front wall of the head and is vertical in position. Its posterior margin is slightly concave, and curves caudad and ventrad to the opposite side of the head, forming a roll-like edge. This roll-like portion is the dorsal part of the head when the latter is in normal position. This region of the head (*28*-4, *ep*) is rectangular, about 0.45 mm.

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* Read plate XXXIV, fig. 4.

wide and 0.62 mm. long. Its posterior edge is concave, as are also the lateral edges which border on the compound eyes, while the anterior margin is quite convex and has a somewhat more than semicircular excision at its median point, in which region is located the frontal ocellus, seen in figures 4 and 5, *fo*, and in 2 in longitudinal section, pl. 28. The epicranium is seen to be flat in surface when the head is viewed in profile. The other two ocelli (*28*-4, *o*) are placed at the two posterior angles of the epicranium, near its margin and slightly posterior to the compound eyes. They are about 0.07 mm. in diameter. The epicranium is divided along its median line by a very plainly cut suture into two equal sclerites. This suture is deep, and in making dissections of the head these two sclerites were often separated readily along this line. The anterior, convex suture between the epicranium and the rest of the head was not so apparent in most specimens that I examined, though usually those boiled thoroughly in potassium hydrate and then carefully cleared in xylol showed it more plainly. The surface of the epicranium is rugose-punctate, slightly pubescent.

The frontal cones, erroneously called "cones of the clypeus" by Slingerland and "face lobes" by Scott,[1] are found, one on each side of the median line, below the epicranium (*28*-4, *fc*). As seen from the front (*28*-5) they diverge from the vertex just beyond the front ocellus. They are separated from the cheeks or genæ by a curved suture, which appears somewhat ovate when the cones are viewed from below. This suture could be made out much more easily on the cephalic than caudal surface of the head.

The genæ (*28*-1, 4, 5, *g*) extend from the cephalic edge of the epicranium down on each side under the compound eyes and fuse with the caudal, folded portion of the epicranium. Between the cones and the compound eyes is the antennal socket (fig. 5, *as*), which is quadrate in shape, with angles much rounded, and with a blunt projection, *p*, breaking into it on its caudal edge, which is concerned with the articulation of the basal segment of the antenna. The aperture filled by the prosternum, procoxæ, frons and mouth parts is similar in shape to that of the epicranium but narrower. On the edge of the gena, midway between the vertex and the compound eye on each side, is situated a sharp projection (figs. 1 and

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[1] Insect Life, vol. V, pp. 229-230.

5, *y*), forming the attachment for a membrane which runs caudad between the front coxæ, and which will be mentioned more fully later. The outline of the compound eye is somewhat more angular than rounded, viewed from either the front or the rear.

In my study of the sclerites of the head I have followed Comstock and Kochi, and my conclusions for *Pachypsylla* agree largely with the facts recorded by them.

ANTENNÆ.

The antennæ are filiform, rather stout (a characteristic of the genus *Pachypsylla*), and average 0.83 mm. long. They are 10-segmented (*28*-3). The relative lengths of the ten antennal segments on the basis of the length of the first segment may be represented thus: 1, 1, 2, 1.2, 1.1, 1.2, 0.8, 1, 0.7, 0.4; the second segment is wider distally than proximally and is distally notched; the fourth, fifth, sixth, seventh and eighth segments are constricted proximally; the tenth segment is the smallest segment and bears at its distal end two stout, blunt, diverging spines (fig. 12), which are about as long as the segment and appear to be hollow. The last few segments are compressed dorsally.

The cuticula of the first two segments is very deeply rugose, forming scales, which on the second segment become longer at the distal end (*28*-3). The surface of the remaining segments is covered with deep, transverse corrugations (*28*-6), which give to each segment a sharply serrate lateral edge, the teeth pointing distad. A fringe of sensory hairs is found on the distal ends of the segments, and a few scattered along their surfaces, the tenth segment being without conspicuous hairs. Figure 9, plate XXXIV, shows the last four segments, with their corrugations and the terminal spines, while figure 6, plate XXVIII, is of the articulation of the third and fourth segment, showing the sensory hairs and the cuticular structure.

MOUTH PARTS.

The suctorial mouth as found in the homoptera, and as described by Meek (1903) and others, consists of labrum, epipharynx, labium, hypopharynx, and setæ. These parts are all represented in *Pachypsylla*. Closely associated with them are the frons, clypeus, mandibular and maxillary sclerites, and tentorium, corresponding in position to those in the cicada, These parts are so closely associated with the mouth parts proper (labium excepted), forming as they do a distinct region of the head, which is torn loose in dissection as a single complex of sclerites (*32*-1), that they will be described in this connection.

On account of the vertical position of the epicranium, the mouth parts assume an orientation by which the frons, clypeus, and labrum are almost horizontal, their distal ends projecting caudad (*28*-5). The basal portion of the labium has a similar orientation, but distad of its bend (*29*-2) it observes a general ventral direction, though possessing some latitude of movement cephalad and caudad.

Frons.—The frons is the largest and heaviest sclerite in this region. Viewed from in front (looking dorsad) it is seen to be obovate in outline (*29*-3). Viewed from the side (fig. 1) its ventral outline is strongly rounded basally, with a dent at about the beginning of the distal third. Its basal edge is thickened (figs. 5 and 1) and continued laterally into processes (figs. 5, 3 and 1) which join the lateral ends of the rod-shaped tentorium, *t*, and the chitinized rods, *cmx*. At the place where the rods *xyz* (fig. 5) above mentioned leave the frons at *x*, same figure, there springs a ligamentary process (*28*-5, *lp*), which runs cephalad and dorsad of frons, forming a small plate above the latter, and this plate in turn is connected to the vertex by two small ligaments. These are for the attachment of the frons to the head, still leaving some opportunity for motion. The frons is rugose-punctate of surface.

Clypeus.—The clypeus (*29*-1, 3, *c*) is about one-third as long as the frons. It is more or less rectangular as viewed from the front, broader at proximal end, and its lateral edge is bent dorsad, thus partly enveloping the stylets or setæ. The slightly curved suture between this sclerite and the frons was clearly marked in most specimens examined, though in a few it was not readily discerned.

Mandibular and Maxillary Sclerites.—Between the lateral edge of the frons and the rod *cmx* (*29*-1), and bounded proximally by the arm of the frons which joins *cmx*, is a more or less circular foramen through which the bases of the setæ may be seen (figs. 3 and 1, *for*). This foramen is bounded distally by two sclerites; the proximal is crescent-shaped and is known as the mandibular sclerite (fig. 1, *mds*); the distal is triangular and extends forward about as far as the end of the labrum and is called the maxillary sclerite (fig. 1, *mxs*). The end of this sclerite has a rather slender, curved portion at its apex, called the "maxillary process." These two sclerites are shown in figure 3 in ventral aspect, and in figure 1 in lateral aspect, where the clypeus, labrum, setæ, etc., have been bent ventrad in order to show the parts free and not overlapping. The edge of the maxillary sclerite and maxillary process are also shown in figure 5 looking ventrad. According to Smith (1892) these two sclerites represent the true mandibles and maxillæ, the setæ not being considered as such.

MOUTH PARTS PROPER. *Labrum.*—The labrum (*29*-3 and 1, *lab*) is only about half as long as the clypeus and differs in shape from the labrum of the cicada in that instead of being a narrow, pointed process, it is, as viewed from in front, rectangular in general shape, slightly longer than broad, with distal corners rounded. It is not so flat as in the cicada, but its lateral edges are bent dorsad in the same manner as those of the clypeus, so as to partly surround the setæ and the pharyngeal canal. At the proximal end of the labrum is found a slightly curved suture between it and the clypeus. This suture was very hard to make out, and the two sclerites in some specimens appeared almost as if fused. Viewed from one side, the ventral outline of the labrum is seen to be slightly convex, with the distal portion bent somewhat ventrad. Marlatt's nomenclature makes the frons the clypeus and the clypeus and labrum a two-piece labrum.

Epipharynx.—Situated under the labrum (*29*-2, 3 and 1, *ep*), and shorter than the same, is an indistinct organ, the epipharynx. In the psyllid this organ is a delicate, fleshy, tongue-like structure, more or less triangular in shape, with a blunt tip, extending as a sort of outgrowth from, and extension of, the labrum. It appears as if it were a prolongation of the labrum, and it was difficult in most cases to determine where the one ended and the other began. The epipharynx is pressed tightly upon the upper surfaces of the setæ, surrounding them somewhat on the sides, and thus supplements the labrum in keeping them together to form a tube.

Labium.—The labium is attached below the hypopharynx, on the lower side of the head (*29*-1, *labi*, and *34*-6). This attachment is by means of a delicate membrane made fast to the edge of the foramen next to the frons, which is easily torn away in dissection. At first the labium is merely a membranous band with only very slightly raised edges, which in this region of the organ are somewhat chitinized. These edges gradually become more raised and lose their chitinization until finally a little before the bend in the labium these edges become broad flaps which come together, and from this point to the tip there is left only a slit (*29*-4). The epipharynx lies naturally against the floor of the labium, but it can be lifted clear, together with the remainder of the parts, for some distance from this position. The first or basal segment of the labium is membranous, not chitinized, since it is so well protected between the procoxæ in a membranous fold. Each procoxa is placed very close to and almost fits the foramen laterad and dorsad of the frons (*29*-1, *for*). The first segment of the labium lies between the front coxæ, embedded in a membrane, and these coxæ almost meet over (ventrad of) it (*29*-2 and *31*-1).

The attachment of the labium to the prothorax, in this case to the region between prothorax and mesothorax, typical of the Homoptera, is very strong as compared with that between labium and head. In fact, in most cases when the head was removed from the rest of the body the labium remained fastened to the thorax but tore loose at its base from the head. Meek mentions such a condition as present in the cicada, calling the structure on the thorax to which the labium is attached a "collar," describing it in the following words: "A heavy membrane attaches the labium to a chitinized collar of the thorax." In *Pachypsylla* this collar is a chitinized process (*27*-4) embedded in the membranes between the prothorax and mesothorax (*29*-2, *p*). This process consists of two heavily chitinized structures, flattened and concave at their distal ends and large and swollen at their proximal ends, which are connected by a curved, chitinous rod as a sort of yoke, which is immediately under or dorsad of, and partly encircles, the labium just cephalad of its bend (*29*-4, *b*). The bases of this process are embedded in the membrane dorsad and somewhat caudad of the cephalic margin of the mesothorax, from whence the process projects ventrad and cephalad. The distal, parallel ends of these are roughened on their edges and hollowed out to form a groove, which, assisted by membranous attachment, holds that portion of the labium just beyond the bend. Connected to the distal ends of these processes are membranes which run cephalad between the bases of the prothoracic coxæ, surrounding the labium, to form a sort of fold or groove for the same. This arrangement may be seen in figure 2, plate XXIX, in diagram, *m* representing the membrane surrounding the labium, *p* the process holding labium to thorax; the position of the labium and setæ may also be seen. Figure 1, plate XXXI, a cross section through the base of the mouth parts and procoxæ, corresponds roughly to Meek's "Fig. 13" for *Cicada*, and shows the great similarity between the two forms. The bases of the membranes surrounding the labium are here illustrated.

The labium is slitted throughout its entire length. At its base, where it is almost flat, it has only short, low, lateral edges or flaps, and hence is broadly open, and the upper parts of the mouth fit into this (*29*-2, 4). The labium, epipharynx and setæ all lie on the floor of the labium. Just at, or a little beyond, the end of the epipharynx the lateral flaps become larger and converge, their wavy margins fitting rather closely together. From here on to the end of the labium these flaps do not diverge again. Figure 6, plate XXXI, represents a cross section of the first segment of the labium just beyond its bend. Here the slit is seen to be held together by means of grooves and ridges. There is also a depression on its caudal wall. The lining of the labial canal is somewhat chitinized. On each side of the canal are found two longitudinal muscles, *m* of the same figure. The first labial segment is much roughened distally; the second is quite short, chitinized, and bears sensory hairs at its distal end; the third segment is heavily chitinized, with a pointed tip ending in two lateral, tonguelike processes. The lateral outline of these is seen in figure 2, plate XXXI, and in cephalic aspect in figure 3. The most notable feature of these processes is the three large sense organs on each—large spines on pegs. These same three sense organs are found on the labium of Aleurodidæ. This segment also bears several large sensory hairs, two of which are much longer than the segment itself.

Pharynx.—This is tube-shaped, chitinized, spreading somewhat at its cephalic end (*29*-5, *p*). Its ventral surface is supplied with eight pairs of muscles and tendons, which run to the inner surface of the frons. At its distal end the pharynx fuses with the hypopharynx and hypopharyngeal lamellæ. The organ is heavily chitinized and thick-walled for some distance, but soon becomes narrower and, losing its chitinization, proceeds caudad until about the middle of the back part of the head, where it turns abruptly caudad and enters the thorax to become the œsophagus.

Mandibles and Maxillæ.—In dissecting the mouth parts the labium is generally torn loose from its connection below the hypopharynx and other parts and left connected to the thorax, as already mentioned. The setæ, however, remain fixed firmly to the upper parts of the mouth (*32*-1) and can be separated and torn loose from these parts only with difficulty. They are held together by the labrum and epipharynx above, the maxillary sclerites and maxillary processes on the sides, and by the hypopharynx below. From this point the bases of the mandibles and maxillæ diverge cephalad and laterad in a manner which has aptly been compared to the form of the letter "Y." The orientation of these parts was best seen in either a lateral view of the frons, clypeus and other parts removed from the head, or by examining the parts in such a position as to look down on the bases of the setæ in the direction of their distal ends. In such a position this divergence, which takes place immediately cephalad of the hypopharynx and other closely enveloping parts, can be plainly seen. The bases of these setæ (*26*-8, 9) are hollow, funnel-shaped, heavily chitinized, and attached to the other parts by tendons and muscles. One pair of these setæ, from their cephalic position, were recognized as the mandibles, and when dissected out were found to surround the other pair of stylets throughout their entire length, their slightly concave inner surfaces fitting closely against them. This latter, inner pair represents the maxillæ. On dissection they were found to be held firmly between the mandibles on each side and were difficult to separate. The mandibles are thicker than the maxillæ, but not so wide. Their relative shapes can be seen in cross section in *31*-5. As in the cicada, the setæ shortly after leaving the head begin to curve so that the mandibles are above and below the maxillæ instead of laterad of them. This curving was seen in sections distad of the bend of the labium and had begun in the section from which figure 5 was drawn. In this figure the lumina in each mandible may be seen. These may also be seen running to the tip when the mandibles are viewed extended, as they are generally filled with air, which renders them visible. No indication of lumina could be found in the maxillæ. They, however, by their concave surfaces fitting together, form a canal through which the plant juices are sucked. The tip of a mandible is very slender, sharp, and sickle-shaped, the convex side bearing blunt serrations, the teeth pointing proximad (*26*-7). The tip of a maxilla is of similar shape but with a sharp projection on the convex side some distance from the apex (fig. 6). The apices of these setæ are so transparent that the details of their structure were difficult to discern clearly.

The homologies of the hemipterous mouth have been much discussed in the past, and the opinions held have been various. I have followed the nomenclature used by Meek for *Cicada*, which seems to be in harmony with late investigations along this line. In their place I have compared the parts of the mouth as seen in *Pachypsylla* with the corresponding parts in *Cicada*. I also found in my work that comparison with other homopterous forms was helpful, showing the close relationship of the Psyllidæ to the other families.

The labium of the Aphididæ is quite similar in general structure to that of *Pachypsylla* except in relative length and number of segments and in the fact that it does not possess the bend characteristic of the latter insect.

The mouth parts, exclusive of the labium, are almost identical with, though larger than, those of the Aleurodidæ which I have examined. The same sclerites are present, arranged similarly, though somewhat differently shaped. The labrum is much shorter and smaller proportionately than in this family, and the setæ seem to be relatively shorter. The end of the labium has the same lateral processes, but these are relatively smaller. The Aleurodid labium has a bend similar to that of *Pachypsylla.*

The coccid mouth parts also correspond in many ways. Here the labium is very short and the setæ are retracted into a special pouch when not in use. The parts exclusive of the labium are similar in general structure to the same parts in *Pachypsylla.* Berlese's nomenclature and figures in his work on Italian Coccidæ were very useful to me. According to this, the clypeus or *ipostoma* (epistoma) corresponds to the frons of *Pachypsylla*, the two terms "ipostoma" and "clypeus" being generally used interchangeably by him. *Cmx* of my figures is the *ipostoma; xyz* is the *rod-shaped apophyse of the clypeus;* the thickened, basal edge of the frons, *z*, is the *transverse bar of the ipostoma;* the opening, *for* (*29*-1), is the *foramen of the ipostoma.* The structure which Meek calls the tentorium is designated by Berlese the *transverse branch of the ipostoma.*

THORAX.

The thorax as described by Riley: "Pronotum moderately short, of equal width, slightly emarginate behind, steeply ascending posteriorly; lateral impressions sculptured and colored as the head; well marked. Dorsulum well developed, thrice as long as the pronotum, and about twice as wide as long; posterior lobe distinctly longer than the anterior; hind margin sinuate each side and truncate at middle; surface finely alutaceous; color, light brownish yellow with a large brown apical spot divided by a yellow median line. Mesonotum convex, wider than head, sculptured as dorsulum, with four vittæ (longitudinal) of brown or greenish-brown color, the outer ones usually wider than the inner ones, all bordered and divided transversely by lines of brighter yellow."

Prothorax.—Viewed from above the thorax is seen to be composed of a number of sclerites, as seen in *27*-3, A and B, which upon closer examination and dissection may be shown to make up the three typical regions of the thorax. In the prothorax there is only one sclerite composing the tergum—the pronotum (*27*-3, A and 31, *pn*). This is collarlike, steeply ascending, as seen in the longitudinal section (fig. 3 B), somewhat wider at the middle than laterad, where an obscure suture divides it from the pleural sclerites. This is shown in plate XXVII, fig. 1, and plate XXXV, fig. 12. The proepisternum and sternum are very closely fused and the suture is scarcely evident. The proepimeron (*27*-1, *em 1*) is a rather wedge-shaped piece, rounded on its ventral end, lying back of the ventral portion of the pronotum and the dorsal portion of the proepisternum. Situated in the pleural membrane beneath the proepimeron is the prothoracic spiracle, *sp.* As seen in *35*-6, the prosternum is only slightly developed, its cephalic edge on each side being produced entad into a slender portion. The prothoracic coxæ are large and occupy, together with the labium, which is imbedded in a membranous fold between the former, most of the prosternal region, leaving the prosternum to develop mostly on the sides. The "collar," already described as a chitinized process holding the labium to the thorax, may be of the nature of the apophyse as seen in the endoskeleton of the mesothorax.

Mesothorax.—The mesothorax is next in complexity of structure, naturally being larger and more complex than the prothorax, as it bears, besides one pair of legs, the fore wings. The tergum is composed of three sclerites (*34*-2, and *27*-3, A, B). Edwards thus describes the mesotergum of the Psyllidæ: "Mesonotum large, generally suborbicular; a portion of its area in front in the shape of a broadly truncate triangle (the *dorsulum*), separated from the remainder by a distinct suture, and a small crescent-shaped piece projecting from the middle of its hind margin (the *scutellum*), also marked off by a suture."

The dorsulum (*27*-3 A and 1) is in shape an equilateral triangle, truncate at its angles, with the edges of the lateral truncations notched. The posterior margin is not straight, but produced on each side into a small projection midway between the median line and the edge of the sclerite. The anterior third of the dorsulum is covered by the posterior edge of the pronotum (fig. 3 A).

The mesonotum (*27*-3 A and 1, *mm*) is the largest sclerite of the thorax, ovate, convex, and about twice as wide as long, with anterior margin almost straight and posterior margin deeply convex. The sclerite is laterally narrowed to a blunt, notched point, which is best seen in lateral view (fig. 1).

The scutellum (figs. 3 A and B, *scu*, and 1) is, viewed from above, ovate, twice as wide as long, lateral edges rounded, anterior margin slightly concave and posterior convex and hollowed out at the median line. The structure of the pleurum of the mesothorax is exceedingly complicated and the sutures are all indefinite. The structure of the same is shown (partly diagrammatic) in figure 1. The suture between the mesosternum and the sclerite just dorsad could generally be made out. This latter sclerite I take to be the mesoepisternum, *es 2*. The mesoepimeron, *es 2*, is a very irregular, much folded sclerite intimately connected with the inwardly extending endoskeleton (fig. 2, *es 2* and *end*). These pleural sclerites are so folded and fused one upon the other that practically only the region of each could be indicated roughly in figure 1. The origin of the anterior wing may be seen in figure 1, *bp*. Just cephalad of its base are two fleshy processes—the cephalic, larger and somewhat reniform in shape; the articulatory epidemes, *artep*. Cross sections show the larger epideme to be almost spherical, with a broad, short base or pettiole.

The mesosternum is rectangular, wider than long, anterior margin somewhat convex, with corners rounded. The coxal cavities or acetabula are large, ovate, and are situated on the posterior margin (*35*-11).

When the mesothorax is dissected free from the other segments, and viewed from behind, the endoskeleton is plainly seen. I shall not attempt to give the orientation and detailed description of its different parts, which may be seen in *27*-2 (partly diagrammatic). This internal skeleton is a complex of plates and rods, braced in all directions, and fused with the outer sclerites of the segment. Three different internal projections may be seen, dorsal, lateral, and ventral. The dorsal piece, the phragma, *phrg*, is a symmetrical, transverse plate projecting ventrad. A similar structure in the mesothorax of a stag beetle is figured by Packard (Textbook of Entomology) and called "Diaphragm for the attachment of the tergal muscles of the metasternum." On each side there is a simple projection which seems to correspond to the apodeme, *apod*. The lower projection or apophyse ("medifurca," according to Packard) is seen at *apoph*, and in *35*-11, and is shaped like a letter "Y"; its dorsal edge is hollowed out, this hollow together with a similar one on the lower edge of the phragma above giving passage to the digestive system, etc. (*27*-33, *c*.)

The mesothorax is built for great strength, the sclerites being much fused and the internal structures all large and heavy. Although this segment carries the anterior wings, which are used mainly in flight, I have no evidence that this insect is a very strong flyer; on one occasion a specimen was captured on the top of a high building, but probably it was carried to such a height independent of its own flying powers, by a strong wind blowing at the time.

Metathorax.—This segment is the strongest in structure of the thoracic segments, and the endoskeleton and external sclerites are so strongly fused that the homologies of this region present a great many perplexing problems. I shall proceed to describe the different parts as I have found them, together with my interpretation as to their homologies. The structure of the notum is not so difficult to determine. Three sclerites are plainly made out (*27*-3 A). The anterior of these is crescent-shaped, and in life is concealed by the scutellum of the mesotergum. The dorsal portion of the second sclerite is a small ovate plate, while the third and posterior sclerite is rather broad, its posterior margin somewhat indented and its lateral margins concave.

The metasternum (*27*-5; *30*-8; *31*-7, *str*) is best developed anteriorally where it is connected with a very light, narrow, median portion between the acetabula, which in turn is connected with and almost seems to be a part of the metafurca, *mf*, of the endoskeleton. Closely connected to the internal pieces of the latter, and separated from the sternum by an obscure suture, is a sclerite whose dorsal end fuses with the other parts. This probably represents the region of the metaepisternum (*31*-7, *es 3*). The portion (*x*) in figure 7 which runs ventrad and entad to join a part of the metafurca has notches on its ventral edge at *x*, and with these notches articulates the end of a complex of sclerites extending down the side and across the ventral surface of the segment (*27*-5 and *31*-8). Much difficulty was found in homologizing these sclerites, authorities differing as to the names of some of the parts. Upon tearing loose this complex carrying the metathoracic leg from its attachment at *x* and *y* (*31*-8) and examining it under a high power of the microscope, its structure could be made out. It is composed of five sclerites. Entad (somewhat caudad and dorsad) is a more or less crescent-shaped sclerite (fig. 8, *str*). This I believe to be a part of the sternum. The next sclerite, *mer*, extad and cephalad, is of a similar shape but bears a blunt projection or tubercle. Authorities differ as to what is the homology of this part. Westwood says: "Beneath, the epimera of the metathorax are singularly produced behind the place of insertion of the hind legs (which are pushed forwards), and terminated by two strong spurs." Edwards states: "Mesosternum produced behind into two large, sharp spines." Riley states: "Metasternal processes cylindrical, hardly narrower toward the tip, which is obtuse, not pointed." I find a similar structure in all the Cicadidæ which I have examined. In "Les Cicadines D'Europe," translated from the German of Fieber by Reiber (1875), in the discussion of the general structure of the Cicadidæ, under legs, this sclerite is called the "meracanthus" ("A la base des hanches et spécialement aux postérieures, naît, visible chez les Fulgorides et remarquablement développée chez Cicada, une épine subulée, au lobe triangulaire, lancéolée, cornée, qui est encore assez distincte aux hanches intermédiaires, Le Dr. Hagen [Die europ. Cicaden, Stett. ent. zeit. 1886] appelle *trochanter* [Klappe] cet appendice corné qui doit être désigné sons le nom vrai de *Meracanthus*, pl. 10, fig. 9, b, car le trochanter n'a pas d'apendice").

Focusing upward with the high power, the next sclerite, also crescent-shaped, with parallel edges, which is seen to be the next extad, comes into view (fig. 8, *em 3*). It is this sclerite which articulates at x and y (figs. 7, 8). This I believe to represent the metaepimeron. Cephalad and laterad of these sclerites is a platelike piece, the cephalic end of which bends dorsad and entad, and forms a ring. This structure is seen in figure 8, *cox*. On this ring, the trochanter articulates (also upon the end of the episternum), and since this sclerite is the only one which in any degree approaches the typical cylindrical coxal form, being in this case a sort of ring at its end, I take it to be the coxa. Entad (dorsad) of this, and slightly cephalad, is an accessory sclerite (*35*-8 and 9, *scl*), a rod whose caudal end is flattened out into a plate to which are attached muscles that arise from the inner surface of the meracanthus, or epimeron (which of these two, I am as yet unable to state). The cephalic end is connected to the cephalic edge of the trochanter and serves to pull it towards the body. Its position is shown in figure 8, plate XXXV.

Turning now to the internal structure of the metathorax, which is best seen from the front, when this segment is severed from the others the metafurca (*30*-8; *31*-7; *27*-5, *mf*) are the most prominent features. The two large forks which proceed dorsad and caudad are connected with the lower surface of the tergum. The whole endoskeleton is so closely fused with the sclerites of the metathorax that it cannot always be separated from them. This internal structure is large and heavy, and by bracing all parts makes the segment exceedingly strong and rigid.

The structure of the pleural sclerites in a species of Aleurodid which I examined was also found to be very complex, there being a large number of sclerites homologous to those found in

Pachypsylla, and a careful comparison of the two forms would throw much light on the question.

The metathorax is not so heavily braced as in *Pachypsylla,* but the coxal region is still well developed. A study of the psyllid pupa would probably show much of interest in this connection, as these parts above mentioned are all represented there but somewhat simplified. The folding and fusion of parts in the adult, and the presence of a heavy, braced endoskeleton and the complex articulation of the trochanter of the metathoracic leg, are all specializations to render possible and increase its jumping power.

My studies on the thorax of the Psyllidæ agree with the recent articles by Snodgrass (1909), in which the old theory of Audouin making each tergal segment to be composed of four primitive sclerites is discredited; I have been able to find no more than three sclerites composing the mesoterga and metaterga.

WINGS.

I. VENATION.

The wing venation of the Psyllidæ seems never to have been reduced to any uniform system such as that of Comstock and Needham (1898-'99). I find the venation figured by Mally, Edwards, Slingerland (1896) and others, but the nomenclature is not uniform and is of a special nature. I have attempted to reduce the venation as seen in the insect under discussion to the system of Comstock and Needham, above mentioned. In this study my first conclusions as to the homologies of the veins were arrived at through the study of adult wings alone, but later I have made use of nymphal wings and wings of newly emerged adults.

On March 6 a large number of pupæ of *Pachypsylla celtidis-gemma* were procured from their galls on the stems (lateral buds) of the hackberry, some seven or eight being found in each large-sized gall. Their wing pads, after soaking for about a day in dilute formalin, were removed, mounted in dilute glycerine, and studied with special reference to their tracheæ. As soon as I had begun this study I found that my conclusions arrived at earlier were borne out in almost every detail by the number, position, character, etc., of the tracheæ of the nymphal wings, these tracheæ corresponding to the veins of the adult wing.

Venation of Nymphal Wing Pads and Wings of Newly Emerged Adults.

Fore Wing (*26*-3 and *32*-8).—The costa, *C*, rises from a large tracheal trunk from the thorax, proximad of the radius and subcosta (fig. 3). It follows the anterior margin, but drops down at the region of the stigma and fuses with the subcosta.

The subcosta, *Sc*, and radius, *R*, are fused throughout the basal third of the wing, and the free portion of the first-named vein is comparatively short, as it soon fuses with the costa.

The radius is represented by a single trachea, and at its base, where it is fused with the base of the subcosta, it rises from the large tracheal trunk, distad of the origin of the costa (fig. 3).

Media and cubitus, *M*, and *Cu*. The media rises from the main trunk just cephalad of the base of the cubitus and distad of the base of the subcosta (fig. 3). It is two-branched and shows its double structure throughout the distal half of the pad, the two branches being close together and parallel for some distance. The three tracheæ, the subcosta plus radius, the media and the cubitus run parallel throughout the basal third of the wing. In normal position, these three tracheæ are very close together, as in figure 8, but in the diagram (fig. 3) they are represented more widely separated to show their connections with the main tracheal trunk from the thorax. The occurrence and relative positions of these three tracheæ are of the greatest importance in correctly determining the homologies of the adult veins, as the upper of these branched veins, formerly called the "upper branch of the cubitus," arises from a trachea distinct from the true cubital trachea, and therefore cannot be a part of the cubitus, while the trachea representing the subcosta plus the radius fused is distinct from those of media and cubitus, though all four veins appear as a single vein in the basal portion of the adult wing. Both media and cubitus are two-branched, their distal ends bending so as to run parallel with the costa for some distance before fusing with it, forming at some places as many as three parallel or more or less intertwining lines of tracheæ (fig. 3).

The anal fold or "claval suture" (fig. 3, *af*) is present as a distinct trachea which fuses at its distal end with the second branch of the cubitus and the costa near the posterior margin. Only one anal vein (fig. 3, *A*) could be made out, but as this trachea was torn more or less when the fore wing pad and the hind wing pad, which are grown together at this point, were separated, such evidence in itself is not conclusive. However, from my studies I have every reason to believe that normally only one anal vein is represented. Likewise, the basal connections of the costa of the posterior margin and the trachea of the anal fold to the main trunk from the thorax could not be accurately determined.

For the further study of the development of the venation, a number of *Pachypsylla celtidis-mammæ* which had emerged during the fall of 1908 were thrown into weak formalin immediately after emergence, before the chitinized veins had been laid down (*26*-4; *32*-9, 10 and 11). In one specimen (*26*-4 and *32*-9) the wing was still delicate and transparent, with its edges crumpled and folded, and the veins still practically in their tracheal condition, while in other specimens the wing membranes had hardened, the pattern gained its pigment, though still light, and the veins fully formed but with the tracheæ in some cases visible within them (*32*-10 and 11). In the youngest specimen mentioned above the three parallel tracheæ of the subcosta plus radius, media and cubitus were strictly separate and corresponded in position to those of the nymph of *P. c.-gemma*. The distal ends of the veins, becoming lost in the folds of the margin of the wing, could not be traced. The position and direction of these tracheæ here were more closely like the veins found in the adult than were those of the nymphal wing pads.

These studies aided me much in studying the development of the tracheæ into veins, and the coalescence of two or more of the former into one vein, as seen in the case of the subcosta plus radius, media and cubitus. In some specimens these could be seen to be still single and parallel until they reached the internal trunk (*26*-4 and *32*-9). The radius and subcosta fused (*32*-10) was on the cephalic margin of the compound vein in process of formation, the cubitus (fig. 11) being on the caudal margin.

The vein in the anal fold could still be plainly seen (*26*-4), but its basal connection was not made out. Since there is no thickening of the wing here, as soon as the air leaves this trachea the only suggestion of a vein that is left is the transparent "fold."

Since there is so little chitinization and thickening of the membrane around the tracheæ of the hind wing, these can be studied best in specimens such as the above, where air in the tracheæ renders them visible. This is especially true of the costa, subcosta and vein in the anal fold. The subcosta cannot be made out in the adult hind wing, and has not been figured for it, but shows plainly when filled with air. By placing a piece of black paper under the condenser of the microscope the veins appear a glistening white, and under the low powers are much more easily studied in this manner.

An interesting point I observed in the hind wing was the presence—in one specimen—of what should probably be regarded as a "sport" vein (*26*-2, *sv*). It is connected with the anal vein and also fuses with the costa. Since I have found in one hind wing of two specimens, both male and female, the radius forked, as is the case with the normal cubitus, which branch, though a "sport," probably points back to a former two-branched condition of that vein as seen in the fore wing, this vein above mentioned may show the same condition for the anal wing, and represent the second anal vein. I find under "Psyllidæ" in the "Zoölogical Record" for 1867 the following: "From the occurrence of irregularities in the venation of the wings of this species, [*Anisostropha ficus* Linn.] he [Frauenfeld] takes occasion to remark upon the frequency of such irregularities among the Psyllidæ; the variation is almost always confined to one wing."

Adult Venation.

Fore Wing (*27*-6).—The costa can be easily traced around the entire margin of the wing and is very thick at the basal portion of the anterior edge. All the rest of the veins except the anal arise from a single main trunk, which is the main support for the wing. This trunk is composed of the three tracheæ mentioned above, fused—the subcosta plus radius, media and cubitus. The subcosta and radius are fused as far as the stigma, *s*, where the subcosta runs up toward the costal margin, forms the lower margin of the stigma, and meets the costa somewhat proximad of the apex of the wing. The radius is composed of a single vein, probably representing R 4 + 5. At about the middle of the cell, *I*, a vein leaves the main trunk which divides into two branches, each of these again dividing once. The two upper branches represent M 1 + 2, and M

3 + 4. In one specimen of *Psylla coryli* I found that on one wing the media was single instead of two-branched, but never found such a case in the present species. The two lower branches above mentioned are *Cu 1* and *Cu 2*. Below this is what is called the "claval suture," corresponding to the anal fold (fig. 46, *af*). The region posterior to the anal fold or claval suture is generally called the "clavus," from the corresponding region in heteropterous wings, *cl.* One anal vein is present; this, by a dorsal and cephalic folding over of the distal half of the margin of the clavus, takes the place of the costa at this point (that is, forms the posterior edge of the wing here), the two veins appearing upon first observation to have crossed. This condition was also observed in the nymphal wing pads and in the wings of newly emerged individuals.

Hind Wing (*27*-7).—This is more simple in venation than the fore wing. The costa soon becomes weak and indefinite. The subcosta is not visible except in newly emerged individuals where the tracheæ are filled with air, and the radius is seen as in the fore wing, as a single vein. The media is also a single vein, though in two specimens I found it two-branched in one wing after the fashion of that vein in the fore wing. The cubitus has two short branches. The claval suture and anal vein are practically the same as those in the fore wing, only there is no folding over of the posterior margin of the clavus.

The adult wings as above described are specialized by reduction, the coalescence of veins being outward.

According to Mally's nomenclature, the common base of the media and cubitus which joins the subcosta plus radius is known as the "Petiolus cubite," *Pc;* the media and cubitus before branching are known as the "first cubitus" and the "second cubitus," and their branches the "first, second, third and fourth furcal veins." The presence of a media is not recognized by him.

Edwards calls the media and cubitus the "upper and lower branches of the cubitus," and the "Petiolus cubite" of Mally the "Stalk of the cubitus." He mentions no media.

Woodworth (1906) adheres to a nomenclature somewhat different. According to this, the media and cubitus are called the "independents" which "appear as a twice-forked branch from the primary," the fact that these veins are distinct, arising from separate tracheæ—as I have shown—not being recognized.

The Psyllidæ are the highest of the group Phytophthires of the Homoptera. These all have simple wing venations, that of the Coccidæ being the simplest. Woodworth says of these: "The venation of the Phytophthires has a nomenclature of its own, not relating it to any other groups, the only investigator who has attempted to homologize the veins being Redtenbacher. This author admits to only two branches as belonging to vein V (corresponding to my independents) [vein *m*] in the Psyllidæ, and sees none at all in the Aphididæ."

II. PATTERN.

Fore Wing.—I quote Riley's original description of the wing markings of this species: "Front wings narrower and, therefore, apparently longer than in *venusta*, very little wider at terminal third than at basal third; costal margin at base but slightly subhyaline, more or less densely covered with small, brownish, scalelike specks, as follows: an oblique and gradually narrowing band (extending from the tip of the pterostigma to near tip of radius), which runs across the wing to the tip of the first furcal, is usually freer from these dots than the rest of the wing, while its edges are usually more crowded with the dots, so as to bring the pale band into greater relief; quite frequently there is an intensified patch of brown about discoidal part of subcostal vein and at all vein furcations; also, the terminal space outside of the pale oblique band is uniformly dark, but with three marginal pale spots (one on each side of the cubital, second marginal and discoidal cells), always more or less evenly speckled; exceptionally, both inside and outside the oblique band, there is a border of variable extent, of a uniform dark brown color, not composed of small dots."

There is great sexual difference in color pattern and in intensity of markings, as seen in figures. The dark border of the light band mentioned in Riley's description is generally very weak in the female, sometimes almost obsolete, except where it crosses the veins, as in figure 6, plate XXXIII. In general, the wing of the male is darker and more heavily marked than that of the female. Also, the spring forms of both sexes are said to be darker than those that emerge in the fall and hibernate over winter.[2]

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[2] Insect Life, vol. V, p. 227.

In the males there is generally a large dark spot between *Cu 1* and *Cu 2,* and on and below the radius proximad of its fusion with the subcosta, this spot tending to spread across cell I. These spots, proximad from the stigma, tend in the female to be reduced to dusky portions only a little darker than the surrounding parts, the former being almost indistinguishable and the latter confined to a border to the vein. The three marginal spots mentioned by Riley are generally more distinct in the male. There is a great deal of individual variation in the wing markings as to the number and arrangement of the small spots composing the pattern, no two individuals showing precisely the same combinations. Figures 1 and 5, plate XXXIII, show how this pattern is produced, and incidentally the difference in shape of the apices of the male and female wings. Figure 4, plate XXXIII, is another view of the pattern at the branching of the median veins, more highly magnified than the two preceding.

The upper surface of the wing is entirely covered with disk-like cuticular outgrowths about 0.005 mm. in diameter, best seen in cross section through the wing (*30*-9, *a* and *b*). These are more or less circular in outline though often very irregular. Some of these, *b*, are filled with dark brown pigment, the same diffusing slightly into the surrounding cuticula. These pigmented disks are arranged in groups of 2, 3, 4, 5, 6, 7, 8, and so on, to form polygons and other figures. These groups form the "spots" which make up the pattern, and are either distinct or banked up together to form a dark spot or band, in which case the polygonal structure is not so apparent. The following elements make up the pattern: (1) The individual pigmented cuticular processes, which I shall designate as "disks"; (2) polygonal and other combinations of these disks—"groups"; (3) arrangements of these groups making up the large and small spots, bands, etc.—"markings."

There are a great many different forms of groups produced by these disks, the principal types of which are seen on page 146. Polygonal groups predominate, though chainlike, broken, and irregular forms are also found. Groups of "two's" and "three's" arranged lengthwise with the wing are found predominating in the basal cells, while more complex polygonal figures are the rule in the distal regions of the wing. Groups consisting of only one disk were not found.

Any difference between the composition of the groups or the frequency of certain group types in the male and the female was not found. The polygonal groups are oftener without the central disk dark than with. When this was not pigmented, the space was still clouded the same as the cuticula surrounding the pigmented disks.

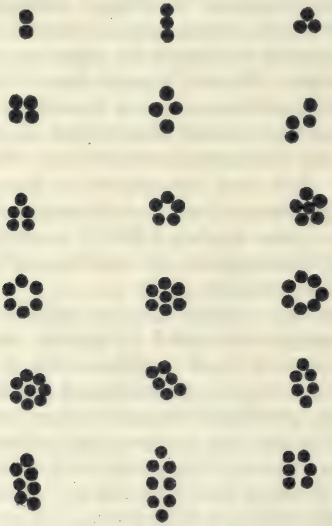

Fig. 61.—Diagram showing principal forms of groups found in the pattern.

The disks were found to be smaller proximad of the base of the wing and near the veins and the anal fold, and consequently the groups there were either of uniformly small disks or of part normal and part small-sized disks. There were no groups on the stigma; here the disks became reduced to mere low, conical projections. The anal fold was smooth and transparent, with clear-cut edges.

Cross section (*30*-9, *c*) shows on the lower side of the wing, opposite each disk, a small, blunt outgrowth, generally unpigmented.

Hind Wing.—Here the disk structure of the membrane is barely visible under favorable conditions of illumination of the microscope. Only those disks on the clavus are pigmented, The number of groups averages thirty to thirty-five. They tend to be irregular and not polygonal. Groups of "four's" are perhaps the most common, being generally found singly, though sometimes two or three groups are associated together to form a figure, generally a chain.

III. STRUCTURE.

Fore Wing.—Of the sixty wings that I examined, the fore wings averaged 2.94 mm. long by 1.19 mm. at greatest width in the male, and 3.27 mm. by 1.37 mm. in the female. Variations in outline of the wings and in the shape of the cells were very slight. There was, however, variation noticed in the length and breadth of the wing between rights and lefts in both sexes.

In the membrane at the base of the fore wings are found two small sclerites, called by Audouin "articulatory epidemes," already mentioned (*27*-1, *artep*). The cephalic of these is seen in cross section to be more or less spherical in outline.

On each side of the wing veins is a row of rather stiff, curved hairs in circular pits, seen in *33*-1 and 5. On the anterior portion of the costa there are three rows of hairs, the anterior of which is separated from the others by a central, dorsally projecting ridge of the costa. From a point near the proximal edge of the light band, already referred to under "pattern," these hairs are found in a single row until the place is reached where the anal vein and the posterior costa seem to cross. From here on the costa bears no hairs, but in their place a row of very minute, sharp teeth on its outer edge. These teeth are also found on the edge of the anterior costa below the smooth-edged cuticular margin of the wing; they are somewhat larger here, but become obsolete a little before the apex of the wing is reached.

Upper and lower surfaces of the wing are essentially the same, as regards number and position of hairs. The structure of the membrane has already been treated. It is submembranaceous in texture.

Hind Wing.—The hind wing averages 2.5 mm. long by 0.97 mm. wide. The apical portion is wider than the basal and is well rounded. The anterior margin is fairly straight, though somewhat undulating in outline. No hairs are found on the veins of the hind wing except two or three on the fused portion of the subcosta, radius, media and cubitus, and on the basal portion of the anterior costa, where fifteen or more—the number being variable—long, stiff hairs project cephalad, curving upward (*33*-8). The hind wings are very weak and delicate, and these hairs are of use in coördinating the movements of the hind wing with those of the fore wing, resembling somewhat the "hamulus" of the Hymenoptera.

The anterior margin of the costa is only slightly roughened —covered with low, knob-like processes, distad of the hairs— the basal two-thirds of its length, but from here on as far as the beginning of the clavus these knobs become lengthened out into spine-like scales pointing distad. The margin of the clavus is comparatively smooth except where roughened at the humeral angle.

The membranes of this wing are transparent and thin, and were often separated from each other to form a sac, when boiled too long in caustic potash. This is in harmony with the studies of Weismann, Künkel d'Herculais, Dewitz, Van Rees and Pratt, which established the fact that insect wings are of hypodermal origin, being evaginations of the integument, and the separation of these membranes through the action of caustic potash shows plainly that the wing membrane is made up of two laminæ, an upper and a lower, which are fused to one another between the veins. The veins, except the costa, are almost without chitinization, and the subcosta could be made out only when it was filled with air as in newly emerged specimens.

The fore wing is quite flat, except the clavus, which is bent somewhat ventrad, and that portion of the clavus between the anal vein and the costa is bent quite sharply ventrad, so that it is almost horizontal in position when the wings are folded along the side of the body. When the insect is at rest and the wings are in this position the anal angles of the fore wings fit up closely against the edges of the scutellum of the mesothorax, and their edges are contiguous from the distal end of the clavus to the tip of the wing. Through the gap between the claval portions of the wings can be seen the posterior margins of the hind wings, which are contiguous throughout the claval region, their anal angles fitting against the small oval sclerite of the metathorax (the second tergal sclerite).

LEGS.

The prothoracic and mesothoracic legs are essentially the same in structure, while the metathoracic leg is greatly specialized. The coxæ of the former are not free and movable, as in many insects, but immovably fixed to the thorax, and, according to Witlaczil, coalescing with it. They are greatly produced laterally, this portion being flattened and longer in the mesocoxa than in the procoxa.

The trochanters are short, cylindrical sclerites, somewhat constricted proximally. All three pairs are similar.

The two anterior pairs of femora are swollen, the outlines of their dorsal surfaces somewhat convex, and the cuticula of ventral surfaces much roughened. The femora of the prothoracic legs are somewhat longer than those of the mesothoracic pair. The distal ends are on their ventral faces deeply gouged out, into which groove, bounded by strong lateral edges, the tibiæ fit when the leg is flexed. The femora of the metathoracic legs are similar in structure to those of the other pairs, but longer and relatively more slender. There was very little variation of this part, as may be seen by the following table of measurements:

AVERAGE LENGTH.

Male.		Female.	
Right.	Left.	Right.	Left.
0.656 mm.	0.654 mm.	0.686 mm.	0.691 mm.

The articulation between femur and trochanter of mesothoracic leg is shown in figure 78, page 150. This is similar in the other pairs.

The structure of the tibiæ is of great interest. The tibiæ of the prothoracic and mesothoracic legs are about as long as the femora, but those of the metathoracic legs are slightly longer than the femora. The distal ends of the first and second pairs of tibiæ bear a fringe of long, sharp spines which point distad, those of the prothoracic pair being slightly the weaker. The distal ends of the metatibiæ are swollen and bear nine short, thick, blunt, black spines (figs 73, 74 and 75). These spines are a part of the scheme of specialization for jumping, preventing the foot from slipping in the same way as do the spines on the grasshopper's tibiæ.

The tarsi are two-segmented. In the first two pairs of legs the second segment is larger, but the first is the larger in the metathoracic pair. In all three pairs the segments are much

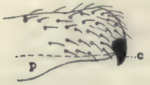

Fig. 71. x 147.

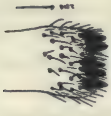

Fig. 73. x35

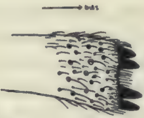

Fig. 74. x35

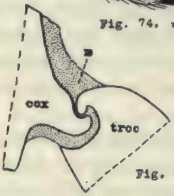

Fig. 78.

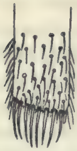

Fig. 75. x35

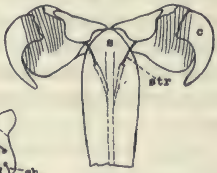

Fig. 79. x300.

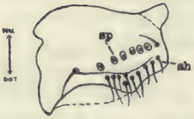

Fig. 77. x 264

FIG. 72.—First metatarsal segment. *c*, claw; *p*, pad.

FIGS. 73 and 74.—End of metatibia showing spines.

FIG. 75.—End of mesotibia.

FIG. 77.—Metatrochanter. *sh*, sensory hairs; *sp*, sensory pits.

FIG. 78.—Articulation between coxa and trochanter mesothoracic leg. *cox*, coxa; *troc*, trochanter; *m*, membrane.

FIG. 79.—Prothoracic foot. *c*, claw; *s*, *str*, tendons moving claws.

constricted proximally. The first segment articulates with the tibia by a joint much like that between femur and trochanter. On the ventral surface of the first tarsal segment of the metathoracic leg is a soft, membranous pad, projecting distad between the two stout, laterally placed claws (fig. 72). This pad is best developed in the metathoracic tarsi and these claws are found only here.

The second segment bears the claws, which are similar in all three pairs of legs. These are short, heavy, and rather blunt, with several small sclerites at their bases embedded in the membrane. These are illustrated in figure 79, which shows the tendons controlling their movement, and the two-lobed empodium, one lobe being under each claw. This empodium is functional, as in many insects, and is used in holding the insect to a smooth surface, as it can cling readily to a glass surface.

Femora, tibiæ and tarsi of all three pairs of legs are covered with hairs, many of which are probably tactile. Both coxæ and trochanters (except of metathoracic legs) bear hairs, the latter with one or two hairs on their distal ends longer than the segments themselves. On the trochanters is a row of oval sensory pits (fig. 77, *sp*).

ABDOMEN.

The relative shapes of the abdomen in the sexes can be seen in *35*-13 and 14 (figure inverted), also in *34*-4. The abdomen of the female is larger than that of the male and seems much longer in proportion, as the ninth segment of the male bearing the genitalia is generally carried bent dorsad and cephalad so that the supra-anal plate fits up tightly against the seventh segment, thus making the abdomen appear quite short. In both sexes it is slightly compressed laterally. According to Edwards, there are visible five segments above and six below, not counting the genital segment.

The first two segments are smaller than those caudad. "The first abdominal somite of both sexes is added to the metathorax to enlarge the springing-gear; the second abdominal somite forms a short stalk for the abdomen. . . ."—(Macloskie.)

According to Witlaczil, in the male the supra-anal plate represents the tenth somite, the ninth is not represented above, and below forms the subgenital plate; the eighth is scarcely at all developed above; in the female, the supra-anal and subgenital plates or valves represent the tenth segment.

In the pleural membrane are found seven spiracles, each surrounded by a wide, chitinized ring. The cuticula of the abdomen is punctate, not so pubescent as that of the thorax, and the membrane between the chitinized plates of each segment is covered with great numbers of minute *sensillia styloconica*. On the posterior edge of each segment is a row of sensory hairs, in prominent pits, much more evident, however, in the male than in the female.

GENITALIA.

Male Genitalia.—The genital segment of the male of *Pachypsylla celtidis-mammæ* is described by Riley as follows: "Male genital segment a little longer than the preceding ventral segment, brown, shining; plate as high as the length of the segment, lateral lobe barely indicated, anterior margin straight, posterior margin very slightly oblique, *i. e.*, the plate gradually increases in width towards the tip, which is truncate and not arctuate, as in the preceding species. Forceps as in *venusta* [two-thirds as high as plate, front margin straight, hind margin slightly sinuate at basal half, tip rounded, outer face smooth and very shining]."

The genital segment of the male consists of the following parts: Supra-anal plate or "genital plate," subgenital plate, forceps or "posterior processes," and copulatory organ or "ædeagus."

The supra-anal plate is a conspicuous fleshy process attached to the anterior edge of the subgenital plate. It is generally carried at about right angles to this plate, and is shown in *35*-10 as drawn forward out of normal position. It averages about 0.48 mm. in length (measured on cephalic surface) and its greatest width is 0.19 mm. Looking cephalad at this plate it is seen to taper at top and bottom, and to be convex with rather wide flaps on its lateral edges (*30*-6, *sppfl*). At its distal end these flaps recede to the edge, where the organ ceases to be an open trough, and becomes a short, rounded, truncate, cone-shaped structure (*30*-6 and 7, *x*), connected by its cephalic wall to the basal wall of the trough below. This structure ends in a short, flaring, membranous ring (figs. 6 and 7, *a*), which is the external opening of the anus. The concave face of the plate is lined with a delicate, folded membrane, between which and the cephalic wall is situated a tube, the rectum. Almost the entire surface of the plate carries numerous long, stiff hairs.

The lower extremity of the supra-anal plate consists of a chitinized ring which expands into a rather broad, two-lobed plate, *lp*, on each side. These plates drop ventrad at their inner edges much after the fashion of a funnel, and form the base of the copulatory organ.

Extending ventrad, with its dorsal edges articulating with the lower side of each of the above-mentioned lobed plates, is a chitinized band or loop (figs. 6 and 7, *l*) extending downward almost to touch the inner surface of the subgenital plate. Between the arms of this loop the proximal portion of the copulatory organ swing, almost entirely concealed within the subgenital plate when the genital segment is telescoped into the next segment cephalad and the supra-anal plate is forced caudad. At emergence, however, the genital organs are extended and not telescoped, and at time of copulation the copulatory organ is protruded from the cavity of the subgenital plate.

Extending ventrad from the lateral plates at the base of the supra-anal plate is the chitinized couplatory organ or extremity of and sheath for the penis—"the ædeagus" of some writers. This organ (figs. 6 and 7, *co*, and *35*-7), soon after it leaves the base of the supra-anal plate, forms a sharp bend, reversing its direction to dorsad. After reaching a position about opposite the middle of the supra-anal plate there occurs a conspicuous swelling, and beyond that a joint or geniculation (*30*-6, *g*). The proximal portion of the second segment of the organ is also swollen. This segment in normal position drops ventrad. The distal end bends caudad and is swollen greatly, becoming club-shaped (fig. 6, *c*), convex cephalad, and concave caudad, this segment having a vertical orientation. The convex, cephalic face of the club is gouged out to form a deep longitudinal groove running from base to tip.

The proximal portion of the first segment of the copulatory organ is not tubular, but slitted on its convex surface, and through this slit the penis enters the sheath, *p*. The concave surface of this portion is coarsely notched or corrugated transversely for some distance beyond the bend. The remainder of the organ is tubular, the canal running through the inner half of the sheath—that is, through the cephalic half of the first segment and through the caudal half of the second segment. This canal runs into the center of the club, makes a sharp turn, and, proceeding back upon itself, curves to the convex side of the club, where it issues at the base of the club in the bottom of the groove above mentioned.

The copulatory organ is more strongly chitinized at its distal end than it is in the curved portion of the proximal segment, and along its outer surface, than on its inner. The first segment measures (from base to geniculation, the distance along curved side being much greater) 0.31 mm., the distal segment 0.38 mm., and the club 0.12 mm.

The subgenital plate has already been mentioned in the quotation from Riley. Its measurements are as follows: Depth, 0.37 mm.; length, 0.40 mm.; greatest width, 0.26 mm.

Situated at the posterior end of the subgenital plate are the forceps (fig. 10, *f*, and *35*-15). These two pieces are somewhat swollen at their bases, seem to be articulated one against the other, and are connected to the subgenital plate by means of a long, thin, tendonous strip, which reaches ventrad to the inner surface of the plate, where it is fastened. The forceps are about 0.29 mm. in length, spread at widest 0.29 mm., and project above the subgenital plate 0.20 mm.

FEMALE GENITALIA.—The genital segment and ovipositor of the female are of great morphological interest. The genital plates have been described by Riley as follows: "Female genital segment a little shorter than the three preceding ventral segments together; . . . upper plate a little longer than the lower one, gradually tapering toward the tip, which is straight; . . . lower plate also simple." This is in substance all that I have found in the literature to which I have had access concerning the female genitalia of this family. The genital valves or plates, being of taxonomic value, have generally been included in descriptions of species, but the ovipositor remains unmentioned, except in a few cases where it is spoken of as "ending in an acute point" (Edwards). Westwood (1839) mentions it as a "pleurivalve conical ovipositor." I have been unable to find anywhere a treatment of its structure.

I shall first treat of the two plates mentioned above, and then consider the structure of the ovipositor proper.

Of these plates, the supra-anal is of the greater interest. It is wedge-shaped, with its apex blunt and its proximal end three-sided. It averages in length 0.98 mm. and in width 0.42 mm. Its shape is well shown in *35*-4, where the ovate openings at its basal angles can be seen. These latter may be of use in attaching the plate to the abdomen. The plate is somewhat convex but not so much so as the subgenital plate. It bears on its upper surface sensory hairs, probably tactile, and is quite heavily chitinized except for a large oval space, *y*, about 0.26 mm. long surrounding the anal opening, where the plate is almost transparent. Along the median line in this space is a slit, into the cephalic end of which the anus opens; this could be seen in a longitudinal-vertical section, where the rectum was found to run just under the dorsal surface of the posterior end of the abdomen and end at the cephalic end of this slit. About midway between this slit and the edges of the clear space are situated the curiously ornamental openings of the circumanal wax glands, outside of which are rather broken and irregular rows of short, heavy, curved, sensory hairs in pits. The dorsal aspect of this region of the plate is represented in *31*-4. This encircling band of wax glands is double; their openings are ovate to rectangular, with borders measuring 0.015 mm. in width, and are seen in the greatly magnified portion shown in *26*-5 B. Longitudinal-vertical sections showed the glands themselves. These are of large size, flask-shaped, with long necks, and are closely packed in a double row under the dorsal openings. They are illustrated in section in figure 5 A, *wg*. Their nuclei, *n*, could in most cases be made out quite plainly. These glands are of hypodermal origin, and are homologous to the circumgenital glands or spinnerets found in the Coccidæ. They are functional in the nymphal stages of most Psyllidæ, and in those forming galls the wax enters into the composition of the gall, making an impervious lining for the cavity, while it is found as a stringy, exuvial covering to some of the nongall-formers. These glands are functional in the nymph of *Pachypsylla*, but I have no evidence that they are so in the adult.

The subgenital plate is much broader and more concave than the supra-anal plate, though not so long as the latter. Its shape when flattened out is shown in *27*-8. The anterior margin is almost straight, except laterad, where it turns caudad and joins the lateral margin, forming an acute angle. The apex is blunt, as in the supra-anal plate. The approximate measurements of the plate are: Width at base, 0.73 mm.; median length, 0.63 mm.; length of lateral margin, 0.67 mm. The plate is covered with rather stiff hairs, probably tactile, more numerous at the posterior end and wanting at the anterior end; it is almost as heavily chitinized as the supra-anal plate.

Ovipositor.—The insects of the suborder Homoptera possess a well-developed ovipositor. This is well preserved and of quite complicated structure in the family Psyllidæ.

The typical structure of an ovipositor is described in the following quotation from Packard: "Morphologically, the ovipositor is composed of three pairs of unjointed styles (*rhabdites* of Lacaze-Duthiers, *gonapophyses* of Huxley), which are closely appressed to or sheathed within each other, the eggs passing out from the end of the oviduct, which lies, as Dewitz states, between the two styles of the lowest or innermost pair and under the cross-bars or at the base of the stylets mentioned; the styles or blades spreading to allow of the passage of the egg."

The structure of this organ I find to be second in interest only to the mouth parts. It is more complicated in structure than those parts in the cicada, but the homologies between the two can be worked out in part, as will be seen later. It is very similar in most points to the ovipositor in the Aleurodidæ.

Lack of material has confined my work to postembryonic studies. There has been much investigation on the segmental origin of the ovipositor parts, the researches of Wheeler and Heymons being of chief importance. Wheeler (1892), who studied orthopteran embryology, holds for the "direct continuity of the embryonic appendages with the gonapophyses," while Heymons (1899), from studies in Heteroptera and Homoptera, considers these gonapophyses as hypodermal outgrowths. However, it is not my purpose to discuss these questions, but to treat of the anatomy and homologies of the parts.

A specimen of *Pachypsylla* female, mounted in balsam after having been thoroughly boiled in caustic potash and cleared, showed, when viewed from the side, the relative position of the ovipositor as regards supra-anal and subgenital plates, and the posterior abdominal segments (*30*-4). The ovipositor is seen to be an elongate organ with dorsal and ventral outlines about parallel. It measures in length about 0.82 mm., in greatest width about 0.19 mm., and in thickness less than half that of width. The caudal extremity is acutely pointed, this portion bending dorsad, then caudad, with its apex extending caudad even with the tip of the subgenital plate, while the supra-anal plate extends caudad from this apex 0.11 mm. in the specimen described. The proximal or cephalic end of the ovipositor is composed of several sclerites of irregular form, to be described later, the ends of which project 0.16 mm. beyond a line joining the bases of the enclosing external plates to a position about opposite and above the last spiracle, well into the dorsal portion of the last abdominal segment. Its position relative to the two plates is shown in figure 1 B, plate XXVI.

Seven longitudinal rods or valves are to be found running throughout the organ. Six of these are paired, two pairs forming the lateral edges of the ventral face of the organ, and a third pair lateral and well towards the dorsal face; the seventh and unpaired rod is dorsal and median.

Each upper and each lower valve of the two ventral pairs are very closely connected, being held together throughout their entire length by means of a tongue on the upper fitting into a groove in the lower, which may be seen in the cross section in *26*-1 A, *tg*. The tips of these valves are very sharp and finely pointed, and come together at their tips, where they are enclosed in a sheath. The cephalic ends of each ventral and inner stylet is connected with a more or less crescent-shaped sclerite (*26*-1, *blv*). The cephalic end of each ventral and outer stylet connects with a sclerite (fig. 1, *buv*) which runs dorsad and caudad. When this reaches about the dorsal face of the ovipositor it turns caudad and becomes a thin rod, *lr*, and at about the middle of the ovipositor becomes compressed laterally to form a wide, thin plate, which gradually loses its chitinization, and is lost in the fleshy tongues on each side of the ovipositor sheath (figs. 1, 2 and 3, *stp*).

Situated medially and a little dorsad of the above-mentioned rods is a rather thick, cylindrical rod bent at its cephalic end slightly dorsad, then ventrad (fig. 1, *mr*). This rod does not project quite as far cephalad as the stylets below. It is greatly swollen at its caudal extremity, with a square end, and its ventral portion is continued into a slender process, in shape much like a human femur, *procv*. This last-named process works against a ventrad-projecting outgrowth of the sheath surrounding the stylet tips, which serves to close the oviduct (fig. 1, *v*). Lying above this slender sclerite are two pairs of chitinized sclerites (figs. 1 2 and 3, *sc 1* and *sc 2*), which are connected with and probably serve to bring about lateral adjustment of the lateral tongues above mentioned. Viewed laterally, these sclerites appear as one pair (fig. 1), but when viewed from above, and pressure was applied to the dissection so as to spread the sides apart, they were seen as two distinct pairs of sclerites. Viewed in this manner, the sclerites of the cephalic pair, *sc 1*, are pointed, with convex inner surfaces. Their tips have a connection with the lateral plates (figs. 1, 2 and 3, *pl*), the latter probably serving to spread these sclerites apart. The caudal pair, *sc 2*, reach almost to the base of the sheath surrounding the stylet tips, are rectangular in shape, with rounded ends, and with their inner surfaces corrugated, the corrugations corresponding to the striations on the surfaces of the lateral tongues of the ovipositor.

The sheath already mentioned (figs. 1, 2 and 3, *sh*) is slitted on its dorsal surface from near its cephalic edge to the apex of the ovipositor, to allow of the spreading of the stylets and the passage of the egg during oviposition. The cephalic portion of its dorsal face carries the small, valve-like, ventrad-projecting process (fig. 1, *v*).

Fig. 1, pl. *26*, shows a cross section about midway through the organ. In this the fleshy structures that were destroyed in boiling in caustic potash can be made out. The grooved and toothed valves, *uv* and *lv*, are seen fitted together, and the chitinized portion, *x*, which is grooved and forms the sides of the oviduct. Above the oviduct, and forming its roof, is the structure, *y*, whose ventral surface is covered with minute, soft, hair-like outgrowths, and whose dorsal portion is chitinized. The part marked *z* probably represents the lateral plates, *lpt*, of *30*-1, 2 and 3. The duct of the cement (?) gland is seen at *cmgd* in this figure and appears in all sections cephalad of this, and in those caudad up to the point where it turns ventrad and enters the oviduct. The entire course of this duct was best seen in longitudinal-vertical sections, but could be traced well in longitudinal-horizontal sections, where its union with the oviduct was plainly seen, and in the next succeeding sections ventrad the oviduct was laid bare. The cement (?) gland itself, a small sac, was found somewhat cephalad of the base of the ovipositor in most of my dissections. Figure 6, plate XXXI, is of a cross section near the base of the ovipositor sheath. Here the shape of the supra-anal and subgenital plates can be seen, also the position of the oviduct. The lateral tongues or sting-palpi are also represented.

I have pointed out the structure of these parts and shall now give my theories as to the homologies. The typical structure of an ovipositor as being composed of several pairs of stylets has already been mentioned.

To homologize the structure of the ovipositor of *Pachypsylla* with the structure of the typical ovipositor is more difficult than the comparison of it with that as seen in the different families of the Homoptera. I find that it is more specialized than a typical ovipositor such as found in the Orthoptera, though it is possible to show the homologies; but since it resembles more closely that found among the Hymenoptera—where it is specialized to form a sting—these homologies can be traced through the latter. Taking the sting of the honeybee as a type of the hymenopterous ovipositor, since this has been so carefully worked out by Cheshire and others, it can be seen that the lower valves of *Pachypsylla* (*30*-1 and 3, *lv*) correspond to the lower and outer pair of *darts* in the honeybee. The upper valves of *Pachypsylla* correspond to the inner pair in the bee, where they are fused into one piece to form the *sheath.* It should be noted here that the *sheath* does not correspond to that part of the ovipositor of *Pachypsylla* which I have designated by that name. In the honeybee there are two fleshy processes, one on each side of the sting, which are thought to represent the upper pair of stylets and are called the "sting-palpi" or "feelers." These are evidently the same as the lateral tongues found in *Pachypsylla.*

The homologies up to this point are comparatively clear, but as to the remainder of the parts I can only theorize, as their structure is complicated and there are present more pieces than in the typical organ. The lateral tongues evidently are the "sting-palpi" and together with the *lateral rods* and *lateral plates* form the upper pair of stylets; but this explanation does not account for the *median rod* with its processes and appendages. There may be three possible explanations for these structures:

1. This *median rod* might be regarded as a fusion of the dorsal pair of stylets, and the *rods* and *lateral plates* only as tendons causing the spreading of the *sc 1* and *sc 2* and consequently the *sting-palpi.*

2. The *rods* and *lateral plates* might be considered as composing the dorsal pair of stylets and the *median rod* as an accessory structure which, moving backward and forward, would spread and close the *sting-palpi,* for these latter are

evidently in as intimate a relation to the *median rod* as the *lateral rods*. Hence, there is possible a third theory:

3. According to Lacaze-Duthier's view, there are "two pieces forming the outer pair of rhabdites" (after Packard), as seen in the figure illustrating his conception of the ideal ovipositor. In *Pachypsylla*, *one* of these "pieces" might be the *rod* and the *lateral plate* which connects basally with the lever supporting the base of the upper valve, *buv*, and distally with the tongues or *sting-palpi*. The *median rod*, then, might represent the second of the "pieces," its two parts fused into one. Thus *rods* and *lateral plates*, together with the *sting-palpi*, would form one portion of the upper pair of valves while the *median rods* represent the other paired portion, fused. The sheath may also belong to the second piece of the upper valves, as do the two pairs of small sclerites, *sc 1* and *sc 2* (*30*-2). The levers supporting the bases of the lower valves, *blv*, find their homologues in similar structures in the honeybee, termed there simply "levers," which are the point of attachment of muscles moving the sting. They have a similar function here, serving to spread the styles.

The ovipositor of the cicada has been described and figured by Marlatt (1895). A rather superficial study of this form from my own dissections has rendered the following facts and hypotheses as to the homologies between this form and *Pachypsylla:* There are found two pairs of blades, the dorsal pair grown together, and the two pairs sliding on one another by means of tongues and grooves much as I have shown to be the case with *Pachypsylla.* The tips of the ventral pair of blades are serrated for cutting purposes. These two pairs of blades evidently correspond to the upper and lower valves or styles of *Pachypsylla*, though in the latter there is no need for their tips to be modified for cutting, as the eggs are not deposited within plant tissue. In *Cicada* there is a very large sheath surrounding the entire ovipositor, except for a slit beneath, which probably corresponds to the supra-anal plate. Marlatt says, "The ovipositor is protected and covered when at rest by two valves, which form a sort of sheath or scabbard." These second valves mentioned by Marlatt, which are dorsad of the blades, proximad are broad, and made up of chitinized and more or less membranous portions, and distad are composed of two distinct and distally separable scabbards covering the tips of the blades dorsally and laterally, and open entad and ventrad. The basal portion is evidently a complex made up of parts corresponding perhaps to the *median rod, lateral rods* and *lateral plates,* with their processes, appendages, etc., of *Pachypsylla,* while the two scabbards may be homologous to the *sheath.* The *sting-palpi* are not represented in *Cicada.*

The ovipositor of one species of Aleurodidæ which I have examined showed features most similar to those of *Pachypsylla* of any other insect, the parts being much more easily compared with those of this insect. The upper and lower pairs of converging blades or styles were found, together with a sheath enclosing their apices, while their bases bore irregular supports as in *Pachypsylla. Sting-palpi* and *sc 1* and *sc 2* were also present.

GENERAL SUMMARY.

1. The head is made up of the typical sclerites.

2. The mouth parts conform in general to those of other homopterous forms, such as those of the Cicadidæ, Aphididæ, Aleurodidæ, and most closely to those of the Aleurodidæ, differing most from those of the Coccidæ.

3. The mesoterga and metaterga show three sclerites only. The pleural sclerites are much folded, with their sutures almost obsolete. The internal skeleton of mesothorax and metathorax is large and heavy, making the segments very rigid.

4. The metathoracic legs are greatly specialized for jumping, the tibiæ being provided with heavy spines on their distal ends, and the coxa, epimeron, meracanthus, a part of the sternum, and an accessory sclerite compose a single complex of sclerites which encases powerful jumping muscles.

5. A study of the tracheation of nymphal wing pads and wings of recently emerged adults has shown that there are present in the adult wing the following veins: one costa; one subcosta; one radius; one two-branched media; one two-branched cubitus; one anal vein; and a vein occupying the anal fold, seen only in nymphal wings, being represented only as a fold in the adult wing. Previous writers have not indicated the media and cubitus as separate veins, but I have shown them to be represented by separate parallel tracheæ in the wing pads. The subcosta of the hind wing, previously unfigured, was found in recently emerged specimens. A sport vein, pos-

sibly representing the second anal vein, was found in one specimen.

6. The color pattern was found to consist of polygonal or irregular groups of pigmented, disklike outgrowths of the cuticula. The manner of producing the pattern is various.

7. The male genitalia were found to consist of supra-anal plate, subgenital plate, couplatory organ and forceps.

8. The female genitalia consist of supra-anal plate (ornamented with a double row of wax glands, flask-shaped in longitudinal section), subgenital plate and ovipositor. The ovipositor was found to be homologous in many points to a hymenopterous ovipositor as seen in the honeybee (a sting). Comparison with other homopterous forms showed it to be homologous in most points with that of the cicada, but almost identical to that of the Aleurodidæ, showing, with the buccal appendages, the close structural relationship of the Psyllidæ to that family.

TECHNIQUE.

My studies have been based upon dissections and serial sections.

Dissections were made in three ways: (1) A dissecting stand fitted with an 0.8-inch lens was used in some cases; (2) some of my work was done under a compound microscope (one-inch eye-piece and one-inch objective) on the lower end of whose draw-tube was placed a three-inch objective, thus producing an erect image. This combination was useful but its disadvantage was that the eye was too far from the specimen being dissected on the microscope stage; (3) the greater part of my dissecting, however, was done under a "Pfeiffer's Erect-vision Dissecting Microscope" using objectives three inch, one inch and two-thirds inch. This was found to be the most convenient, especially in the more delicate dissections, such as of mouth parts and genitalia. By the use of very fine, sharp-pointed needles, these minute organs could be torn apart with ease.

Most of my material was boiled for a short time in caustic potash, and then treated with alcohol and xylol previous to dissections, no fresh specimens being available at the time when this work was done. Xylol was of great use in clearing the parts, but at the same time it rendered them brittle and easily broken.

Dissections were made under water, alcohol, xylol and glycerine. Xylol was a very clear medium, having the advantage that uncleared specimens could be dissected in it, soon becoming clear, but it evaporated very quickly, and, lacking viscosity, allowed too much movement of the parts being dissected. Glycerine was found to possess the necessary viscosity and was the most satisfactory medium in most cases.

The nymphal wing pads were removed with fine scissors, holding the nymph the while between the finger-tips; the pads were mounted in dilute glycerine after being kept in formalin for about twenty-four hours.

Serial sections were made through the mouth parts and genitalia, and cross, longitudinal-horizontal and longitudinal-vertical sections through the entire insect.

Killing and Fixing.—Live insects were killed by plunging into a boiling saturated solution of corrosive sublimate containing about one per cent of acetic acid, and after being punctured with a piece of glass drawn out into a fine point were left in the solution to fix for twenty-four hours.

Dehydrating and Clearing.—The insects were placed in small vials with ends covered with cheesecloth, and run through alcohols of percentages 70, 85 and 95, twenty-four hours in each. They were removed to absolute alcohol for about twelve hours and then run into xylol for about twelve hours.

Infiltration and Embedding.—Leaving the specimens still in the vials they were infiltrated in a paraffin oven with paraffin of melting-point 50-55° C. for forty-eight hours. They were then embedded in paraffin in small paper dishes, being oriented properly as the paraffin hardened when the dish was floated on cold water.

Sections.—Serial sections 10-20 microns thick were cut on a sliding microtome. The ribbons were floated onto Mayer's albumen fixative on a clean slide, the excess of fixative drained off with filter paper, and the slide dried on top of the paraffin oven for twelve or more hours. The slide was then left for ten to fifteen minutes in xylol to remove the paraffin, when it was run through the following grades of alcohol, five to ten minutes in each: 95 per cent, 85 per cent, 70 per cent, 50 per cent, 35 per cent, 25 per cent, and then into water, after which the sections were stained in Mayer's Carmalum, ten to fifteen minutes, washed in water and run back through the alcohols, beginning with twenty-five per cent, into absolute alcohol, five to ten minutes in each. They were then cleared in xylol and mounted in balsam.

In running the sections into and out of the stain (aqueous) the lower grades of alcohol, 25 per cent and 35 per cent, and then water, were necessary, as without their use the transfer into the stain from 70 per cent alcohol was found to be too sudden, causing currents which tore the sections loose from the slide. Any dirt or grease on the slides made this more certain. However, cleaning the latter in 95 per cent alcohol containing a few drops of hydrochloric acid obviated this.

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CONTENTS:

INVESTIGATIONS REGARDING THE PHLOEM AND FOOD-CONDUCTION IN PLANTS, ... *Frank U. G. Agrelius.*

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INVESTIGATIONS REGARDING THE PHLOËM AND FOOD-CONDUCTION IN PLANTS.

BY FRANK U. G. AGRELIUS.

Plates XXXVI-XXXVII.

THIS work is an inquiry into the special devices for the lateral transfer of food materials in the phloëm of vascular plants; to see whether sieve tubes are always present in the higher plants; and to make some comparative studies of the phloëm in stems, petioles and fruitstalks.

At first material in the winter condition was tried but did not prove satisfactory, on account of the difficulty of identifying the sieve tubes in their winter condition. Material was again collected, this time including stems, petioles and fruitstalks, from the spring and summer growth, where the sieve tubes were functioning. Vines were selected at first, from the supposition that the conducting elements would be better developed and therefore plainer. This material was preserved in two-per-cent formaldehyde. As shrinkage of the protoplasm would really assist in making the cell walls more distinct, but little attempt was made to prevent it in the various processes of preparation.

The celloidin method of imbedding was tried at first but it did not serve the purpose well. It was rather essential in the hard material first collected, but the paraffin method worked better in most cases. By the celloidin method slides having the required large number of sections upon them were difficult to make. If the celloidin were left in the sections it stained too much like the cellulose walls. If dissolved out the cuttings were liable to cupping or to injury in the region of the cambium. These facts led to the choice of the paraffin method, which was used where possible and which proved quite satisfactory in the majority of cases. The oldest material possible was commonly used.

Stains adapted to the work in hand were not found at first. Iodine green and erythrosin were tried, but this method left the phloëm red or pink—a poor color for the purpose. Finally fuchsin for the lignified walls and methyl blue for the cellulose ones were found to be quite satisfactory. The latter gave a fairly dark wall and slime body—the one better for making the drawings, the other rendering the identification of the sieve tubes less difficult.

The sections of such varied kind as to subject and age of material stained quite differently under the same treatment, so that each one usually required some variation. The slides were left in the fuchsin from two hours to several days. The excess stain was removed with acid-alcohol, and the slides were then placed in methyl blue for from twenty seconds to three or four minutes.

As a rule, cross, radial and tangential sections, with many mounts on each slide, were prepared for each subject—in all, more than 300 slides. These included specimens from young and from somewhat older material. The tangential sections proved the best for demonstrating sieve tubes. The cross sections were best for the measurements of cell walls and cell cavities, and to show the locality of the various tissues, etc. All were used to determine, if possible, the presence of pits, or of any other facts bearing on the problem.

PLANTS EXAMINED.

The following is a list of the plants examined, arranged according to the classification of Gray's revised manual:

- Pinaceæ:
  - Pinus laricio Port.
- Alismaceæ:
  - Sagittaria latifolia Willd.
- Gramineæ:
  - Zea Mays Linn.
- Cyperaceæ:
  - Scirpus validus (Vahl.) L.
- Bromeliaceæ:
  - Tillandsia usneoides L.
- Liliaceæ:
  - Yucca glauca Nutt.
  - Asparagus officinalis L.
  - Smilax rotundifolia L.
- Salicaceæ:
  - Salix alba, var. vitellina (L.) Koch.
  - Populus alba L.
  - Populus deltoides Marsh.
- Juglandaceæ:
  - Juglans nigra L.
- Urticaceæ:
  - Ulmus fulva Mx.
  - Ulmus americana L.
  - Celtis occidentalis L.
  - Cannabis sativa L.
  - Humulus Lupulus L.
  - Morus rubra L.

- Aristolochiaceæ:
  - Aristolochia macrophylla Lam.
  - Aristolochia tomentosa Sims.
- Ranunculaceæ:
  - Clematis Pitcheri T. & G.
- Anonaceæ:
  - Asimina triloba Dunal.
- Menispermaceæ:
  - Menispermum canadense L.
- Saxifragaceæ:
  - Deutzia Fortunei Hors.
- Rosaceæ:
  - Spiræa japonica L. (?)
  - Pyrus Malus Linn.
  - Fragaria virginiana Deuchesne.
  - Rubus occidentalis L.
  - Rubus cuneifolius Pursh.
  - Rosa pratincola Greene.
  - Prunus americana Marshall.
- Leguminosæ:
  - Gymnocladus dioica (L.) Koch.
  - Gleditsia triacanthos L.
  - Melilotus alba Desr.
  - Amorpha fruticosa L.
  - Desmodium canescens (L.) DC.
- Rutaceæ:
  - Zanthoxylum americanum Mill.
- Simarubaceæ:
  - Ailanthus glandulosa Desf.
- Anacardiaceæ:
  - Rhus glabra L.
  - Rhus toxicodendron L.
  - Rhus cotinus L.
- Celastraceæ:
  - Celastrus scandens L.
- Aceraceæ:
  - Acer saccharinum L.
  - Acer Negundo L.
- Rhamnaceæ:
  - Rhamnus lanceolata Pursh.
- Vitaceæ:
  - Psedera quinquefolia (L.) Greene.
  - Vitis æstivalis Mx.
- Tiliaceæ:
  - Tilia americana L.
- Malvaceæ:
  - Abutilon Theophrasti Medic.
- Cactaceæ:
  - Opuntia Rafinesquii Engelm.
- Haloragidaceæ:
  - Myriophyllum heterophyllum Mx.
- Cornaceæ:
  - Cornus asperifolia Mx.
- Oleaceæ:
  - Fraxinus viridis Mx. (?).
  - Syringa vulgaris L.
- Asclepiadaceæ:
  - Asclepiodora viridis (Walt.) Gray.
  - Asclepias syriaca L.
- Convolvulaceæ:
  - Cuscuta glomerata Choisy.
- Labiatæ:
  - Monarda fistulosa L.
- Solanaceæ:
  - Lycium halimifolium Mill.
- Scrophulariaceæ:
  - Verbascum Thapsus L.
- Bignoniaceæ:
  - Tecoma radicans (L.) Juss.
  - Catalpa speciosa Warder.
- Plantaginaceæ:
  - Plantago virginica L.
- Caprifoliaceæ:
  - Symphoricarpos orbiculatus Moench.
  - Triosteum perfoliatum L.
  - Sambucus canadensis L.
- Cucurbitaceæ:
  - Cucurbita pepo L.
- Compositæ:
  - Brauneria pallida (Nutt.) Britton.
  - Gaillardia grandiflora ?
  - Arctium Lappa L.
  - Cirsium discolor (Muhl.) Spring.
  - Lepachys pinnata (Vent.)

These range from the Pinaceæ to the Compositæ. They include one parasite, one epiphyte, three hydrophytes and two xerophytes. The list embraces twenty-three herbaceous plants (not including vines), five herbaceous vines, ten shrubby vines, thirteen other shrubs and twenty-one trees. These are em-braced in thirty-nine families, sixty-five genera, and seventy-two species.

DRAWINGS.

In general, camera-lucida drawings have been made to show the pits in the phloëm when found, to show sieve tubes and some of the adjacent tissues from three points of view. A Bausch and Lomb 1/12 objective was used with but few exceptions, and for measuring a Bausch and Lomb micrometer eyepiece—divisions 1/10 mm. In all about 175 drawings have been prepared for use in evidence.

FINDINGS.

PROBLEM I.—What special devices occur for the lateral transfer of food materials in the phloëm?

After considerable search I have found pits in the lateral walls of the phloëm of fourteen plants, as shown, for example, in figures 1 and 2. In figure 1 they are evidently between the medullary ray and the phloëm; in figure 2, between the sieve tubes and the adjoining cells.

Frank[1] seems to imply that there are no pits between the parenchyma cells of the phloëm. Figure 1 shows some as they appeared between the parenchyma and the parenchyma, and between the parenchyma and medullary-ray cells of the stem of *Populus alba*. He also states that the sieve tubes are the widest phloëm elements.[2] This is hardly true in quite a number of instances, as in *Amorpha fruticosa* (fig. 6), where the parenchyma is the wider. Quoting from Briosi,[3] he states that the slime bodies of the sieve tubes sometimes contain starch granules. Some are shown in figure 7 in *Populus alba*. They were noted also in *Rhus toxicodendron*. Frank states also[4] that the lateral walls of the sieve tubes are never strengthened. Figures 4 and 5 show thickenings on the lateral walls of the sieve tubes in the roots of *Populus deltoides*. It would seem that these are for strengthening the wall. They occur also in the end plates of the sieve tubes of the same plant (figs. 8 and 9) and in *Populus alba*.

Strasburger[5] finds pits between the phloëm parenchyma and the medullary rays. Figures 1, 2 and 3 show such. He also states[6] that the cortical rays are specially adapted by means of these pits and their contact with the companion cells for taking up and transferring the food materials laterally, especially to the cambium. Figure 6 shows a very common arrangement of the medullary rays which bears out the rest of his statement. It may be added to by saying that the medullary rays are often close to each other tangentially, and the rays and ray-like cells of the pericycle often sweep around the narrow portions of the phloëm, as seen in figure 6 of *Amorpha fruticosa,* as though for the special purpose stated above, and in a way especially fitting them for that function. Some recent research[7] has further verified Strasburger's statements in certain plants.[8]

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[1] Frank, A. B.: Lehrbuch der Botanik, 1892, vol. I, p. 184.

[2] Loc. cit., p. 188.

[3] Loc. cit., p. 188.

[4] Loc. cit., p. 188.

[5] Strasburger, Ed., Textbook of Botany, 1897, p. 135. (Trans. by Porter.)

[6] Loc. cit., p. 135.

One thing to be noted in botanical literature is that work on sieve tubes and sieve plates is usually done with plants from the Vitaceæ, Cucurbitaceæ, Tiliaceæ, and a few others, where, as will be seen by reference to table I, the walls of the phloëm are unusually thick. Presumably this is because here the things to be seen are more pronounced, and hence more easily found and studied. Table II shows comparative data collected from the plants having pits in the lateral walls of the phloëm as observed in this work and from those in which such pits were not observed. In *Equisetum* pits are general in the phloëm elements and in the rest of the cortical tissues. In others this is not true. In the tables mentioned it will be seen that pits are present in those plants having thicker walls than those in which pits were not observed, and, as a rule, the sections were from actively functioning tissue. It is seen that the phloëm walls are as thin in some cases as 0.25 micron, and in many cases 0.35 micron. In fact, in the phloëm in many instances there was but little evidence of appreciable addition in thickness to the original vertical wall formed by the cambium or procambium. As a result of this, in drawing with the high magnification of 1200 diameters, it was not feasible to use a double line for representing the thickness of the walls, and the attempt to do so was soon abandoned and choice made of the measurement and tabulation method as shown by the tables. It is quite plain that such thin walls could neither have nor require pits. In the xylem I found pits invariably present, but with the cell walls always much thicker. Even here there are no actual perforations.

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[7] Hill, A. W., Histology of the Sieve Tubes of Angiosperms. Annals of Botany, vol. 22, No. 86, pp. 246-290.

[8] Sykes, M. G., Anatomy and Histology of *Macrocystis pyrifera* and *Laminaria saccharina.* Annals of Botany, vol. 22, No. 86, pp. 291-326.

Plants often adopt the device of obliquely placed end plates, possibly for the purpose of furnishing greater surface for the pits. This is noticeably true in many instances, especially in the Salicaceæ. As a result it seems necessary to strengthen these walls, and cross banding with thickenings in the walls are seen in figures 2, 8 and 9. The best illustrations (figs. 8 and 9) are from a root of *Populus deltoides*, taken about eight feet below the surface of the ground. Here there is a much increased sieve-plate surface, with strengthening bands at regular intervals, as seen from two directions.

Problem II.—Are sieve tubes always present in the phloëm?

As to this problem, my data, many of which were obtained only after long search, are quite positive. Plants differ greatly in arrangement, location, number, size, staining qualities, etc., of their sieve tubes in the various specimens. However, one can be reasonably sure of their presence by noting the phloëm in cross section. The companion cells and the sieve tubes adjoining form units in outline, which, together with the protoplast of the companion cell and the slime body of the sieve tube, assist in the discovery (fig. 6). Sieve plates are not so easily found, unless it may be in those plants where sieve tubes are numerous, or where one happens to get a section through an unusually favorable place. For still better evidence the slime body is good, but the perforated sieve plate is best. I was usually not satisfied until all of these requirements were met, and the drawings were then made.

Perforations were not found in the end plates in *Pinus laricio*, *Sagittaria*, and *Asparagus*. They were quite numerous, although very small, in *Opuntia*. In *Myriophyllum*, a hydrophyte, they were evident, as in *Cuscuta*, a parasite. In this last were found cells of large dimensions, apparently serving especially as conducting cells. One was 0.1 mm. in tangential diameter by 1.62 mm. in axial length. We could not tell how much longer, because of the limits of the section. Sieve tubes are also present in *Tillandsia*, an epiphite. Here there is a cylinder of sclerenchyma inclosing the vascular bundles, and probably permitting of but little lateral transfer of foods.

Data concerning the sieve tubes are contained in tables I-IV.

It will be seen that the walls are commonly quite thin—those between them and the companion cells being thinnest. Thickness of their walls ranges from 0.25 micron to 4.17 microns.

PROBLEM III.—The facts observed concerning the third part of the problem are tabulated in table III. The tendency is shown to be toward a reduction of the diameter of the vessels in the fruitstalk and petioles, with an increase in thickness of the walls.

RESUME.

First.—There are special devices for the better lateral transfer of foods present in the phloëm and cortex of the plants studied. These are (*a*) pitted walls; (*b*) the arrangement of the phloëm in narrow wedges with pericycle cells sweeping around these and connecting with the medullary rays, and (*c*) radially elongated medullary-ray cells adapted readily to conduct the food as stated. It is probable that in many plants the extreme thinness and large area of the phloëm walls permits a considerable lateral movement of materials without resort to pits, and that no pits are to be found in some (perhaps many) cases.

Second.—Sieve tubes with perforated sieve plates were demonstrated in all but three of the plants examined, and here I was satisfied of their presence. They often increase the area of their sieve plates by placing them obliquely, and these may require special thickenings to support them. The number of the sieve tubes in various species varies considerably. They are present in some plants when probably almost functionless.

Third.—Relatively, the phloëm and xylem do not vary greatly in amount in the various parts of the plants, such as the stems, petioles, etc., but the main differences in this respect are in the other tissues.

TABLE I. Thickness of cell walls in stems (measurements in microns).

	Between adjoining sieve tubes..	Between sieve tubes and companion cells.....	Between sieve tubes and medullary rays......	Between tracheal tissues and xyl. parenchyma....	Between tracheal tissues and medullary rays......
Pinus laricio Bort.	0.65	....	0.65	2.58	1.60
Saggittaria latifolia Willd	0.35	0.32	....	1.50	....
Zea mays L.	0.50	0.40	....	1.65	....
Scirpus validus L.	0.30	0.25	....	1.50	....
Tillandsia usneoides L.	0.30	....	....	1.30	....
Smilax rotundifolia L.	1.00	0.60	....	1.65	....
Yucca glauca Nutt.	0.58	0.40	....	1.78	....
Asparagus officinalis L.	0.35	0.30	....	2.79	....
Salix alba, var. vitellina (L.) Koch.	0.40	0.35	0.40	1.85	1.28
Juglans nigra L.	0.35	0.30	0.35	2.73	1.65
Populus alba L.	1.08	0.53	1.25	2.73	1.65
Populus deltoides Marsh.	0.50	0.35	0.50	2.80	1.85
Ulmus Mx fulva.	0.35	0.30	0.35	3.53	2.61
Ulmus americana L.	0.40	0.35	0.35	3.83	1.67
Celtis occidentalis L.	0.35	0.25	0.40	2.31	1.56
Cannabis sativa L.	0.35	0.25	0.35	2.60	1.72
Humulus lupulus L.	0.30	0.30	....	3.86	....
Morus rubra L.	0.35	0.30	0.35	2.75	1.60
Asimina triloba Dunal	0.40	0.35	0.55	3.08	....
Clematis pitcheri T. & G.	1.28	0.92	....	3.72	3.50
Menispermum canadense L.	0.45	0.40	....	2.48	....
Deutzia fortunei Hort.	0.42	0.40	0.35	3.72	2.78
Spiræa japonica L.?	0.35	0.25	0.25	1.58	....
Pyrus malus L.	0.50	0.40	0.55	3.11	1.72
Rubus occidentalis L.	0.45	0.45	0.35	2.19	1.75
Rubus cuneifolius Pursh.	1.65	1.71	3.30	3.65	1.85
Prunus americana Marshall.	0.60	0.40	0.55	2.43	1.92
Gymnocladus dioica (L.) Koch.	0.40	0.30	0.45	3.94	3.16
Gleditsia triacanthos L.	0.65	0.30	0.58	2.94	2.46
Melilotus alba Desr.	0.40	0.25	0.40	3.93	1.85
Amorpha fruticosa L.	0.45	0.35	0.40	2.80	1.65
Desmodium canescens (L.) DC.	0.40	0.33	0.40	2.70	2.08
Zanthoxylum americanum Mill.	0.55	0.35	0.50	3.37	3.25
Ailanthus glandulosa Desf.	0.50	0.35	0.45	4.48	3.61
Rhus glabra L.	0.75	0.55	0.75	2.64	2.20
Rhus toxicodendron L.	0.40	0.35	0.50	1.85	1.85
Rhus cotinus Nutt.	0.55	0.55	0.90	2.35	1.50
Celastrus scandens L.	0.50	0.38	0.50	3.08	1.85
Acer saccharinum L.	0.68	0.55	1.00	2.35	2.00
Acer negundo L	1.00	0.45	0.85	2.60	1.87
Rhamnus lanceolata Pursh.	0.50	0.35	0.70	2.50	1.80
Psedera quinquefolia (L.) Greene	0.70	0.50	0.50	2.20	1.85
Vitis æstivalis Mx	2.33	1.72	4.17	3.83	1.77
Tilia americana L	0.55	0.50	1.00	2.48	....
Abutilon theophrasti Medic	0.65	0.45	0.80	3.25	....
Opuntia rafinesquii Engelm	0.50	0.38	....	1.66	....
Myriophyllum heterophyllum Mx	0.50	0.30	....	3.10	....
Cornus asperifolia Mx.	0.45	0.25	0.40	3.50	2.08
Fraxinus viridis Mx.?	1.15	0.75	1.30	4.47	2.27
Syringa vulgaris L.	0.60	0.40	0.80	2.85	2.02
Cuscuta glomerata Choisy	0.42	0.35	....	3.40	....
Lycium halimifolium Mill	0.60	0.35	....	3.80	....
Tecoma radicans Juss	0.55	0.40	0.45	3.02	2.13
Catalpa speciosa Warder	0.45	0.25	0.30	2.46	2.15
Sambucus canadensis L.	0.50	0.30	0.55	5.56	2.30
Triosteum perfoliatum L.	0.60	0.40	0.50	4.44	....
Symphoricarpos orbiculatus Moench	0.60	0.40	0.50	2.78	1.92
Brauneria pallida (Nutt) Britton.	0.65	0.35	....	2.68	....
Gaillardia grandiflora	0.50	0.45	....	3.25	....
Minimum thickness of wall	0.300	0.250	0.250	1.300	1.280
Maximum thickness of wall	2.330	1.720	4.170	5.560	3.610
Average thickness	0.598	0.430	0.715	2.866	2.095

TABLE II.

	Thickness in microns of walls between—				
	S. t. and s. t.	S. t. and comp. cells.	S. t. and m. ray.	Tracheal tissues and xyl. par.	Tracheal tissues and m. ray.
Pinus laricio Bort	0.65	....	0.65	2.58	1.60
Yucca glauca Nutt	0.58	0.40	....	1.78	....
Salix alba, var. vitellina (L.) Koch	0.40	0.35	0.40	1.85	1.28
Populus alba L	1.08	0.53	1.25	2.78	1.65
Populus deltoides Marsh. (stem)	0.50	0.35	0.50	2.80	1.85
Populus deltoides Marsh. (root)	1.39	1.00	1.22	4.88	3.24
Menispermum canadense L	0.45	0.40	....	2.48	....
Rubus occidentalis L	0.45	0.45	0.35	2.19	1.75
Gymnocladus dioica (L.) Koch	0.40	0.30	0.45	3.94	3.16
Celastrus scandens L	0.50	0.38	0.50	3.08	1.85
Psedera quinquefolia (L.) Greene	0.70	0.50	0.50	2.20	1.85
Vitis æstivalis Mx	2.33	1.72	4.17?	3.83	1.77
Abutilon theophrasti Medic	0.65	0.45	0.80	3.25	....
Symphoricarpos orbiculatus Moench	0.60	0.40	0.50	2.78	1.92
Average for the above plants with pitted walls	0.763	0.556	0.941	2.884	1.993
Average from plants where pits were not observed	0.549	0.394	0.633	2.922	2.133
Difference (+) or (−)	+0.214	+0.162	+0.308	−0.038	−0.140

TABLE III. COMPARISON OF WALL THICKNESS IN STEMS, PETIOLES, AND FRUITSTALKS.
(Measurements in microns.)

	Walls between s. t. and s. t.			Walls between s. t. and comp. cell.			Walls between s. t. and m. rays.			Diameter of sieve tubes.			Walls between tr. and xyl. parench.			Walls between tr. and m. rays.			Diameter of tracheals.			Length of sieve tubes.		
	Stems.........	Petioles.......	Fruitstalks ...	Stems.........	Petioles.......	Fruitstalks....	Stems.........	Petioles.......	Fruitstalks ...	Stems.........	Petioles.......	Fruitstalks....	Stems.........	Petioles.......	Fruitstalks....	Stems.........	Petioles.......	Fruitstalks ...	Stems.........	Petioles.......	Fruitstalks ...	Stems.........	Petioles.......	Fruitstalks....
Vitis æstivalis Mx.	2.33	2.37	......	1.72	2.33	....	4.17?	2.33	......	20.83	14.25	......	3.83	3.09	......	1.77	2.92	......	72.90	36.40	......	....	..	..
Rubus cuneifolius Pursh.	1.65?	1.80	......	1.71?	1.55?	....	3.30?	1.50	......	13.03	8.45	......	3.65	4.02	......	1.85	2.24	......	41.47	28.35	......	....	..	..
Cannabis sativa L.	0.35	0.35	......	0.25	0.30	....	0.35	0.35	......	18.38	19.89	......	2.60	3.42	......	1.72	3.42	......	33.96	27.70	......	....	..	..
Rhus glabra L.	0.75	......	0.50	0.55	....	0.50	0.75	......	0.60	12.08	......	7.83	2.64	......	2.55	2.20	......	1.65	32.40	......	13.75	....	..	..
Desmodium canescens DC.	0.40	......	0.35	0.33	....	0.35	0.40	......	0.35	6.33	......	4.92	2.70	......	2.00	2.08	......	......	17.43	......	9.95	....	..	..
Verbascum thapsus L.	0.50	......	0.50	0.45	....	0.30	0.45	......	0.45	12.08	......	10.96	3.27	......	3.10	1.83	......	2.25	33.78	......	23.81	230.85	..	..
Rhamnus lanceolata Pursh.	0.50	......	0.50	0.35	....	0.40?	0.70	1.70	0.75	13.16	11.53	5.08	2.50	4.00	3.50	1.80	3.33	2.16	23.76	15.95	15.75	97.6	..	..

TABLE IV. *Resume.*
(Measurements in microns.)

	Walls between sieve tubes and sieve tubes.	Walls between sieve tubes and comp. cells.	Walls between sieve tubes and med. rays.	Diameter of sieve tubes.	Walls between tracheals and xyl. parench.	Walls between tracheals and med. rays.	Diameter of tracheals.	Length of sieve tubes.
Stems, only.	0.598^{61}	0.430^{59}	0.715^{46}	12.193^{9}	2.866^{62}	2.095	33.633^{13}	183.608^{4}
Petioles, "	1.317^{4}	1.093^{3}	1.470^{4}	13.166^{5}	3.526^{5}	2.997^{3}	30.612^{5}	....
Fruitstalks, only	0.504^{11}	0.364^{7}	0.528^{7}	8.302^{10}	2.884^{11}	2.229^{7}	15.830^{10}	182.180
Roots, only.	1.390^{1}	1.000	1.220	41.640	4.880	3.240	206.55	....
Minimum...	0.300	0.250	0.250	3.500	1.300	1.280	9.950	97.600
Maximum ..	2.330	1.720	4.170(?)	41.640	5.560	3.610	206.55	256.780
Average....	0.622	0.471	0.746	12.009	2.936	2.166	32.845	183.608

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HISTOLOGY OF TOWNSENDIA EXSCAPA AND LESQUERELLA SPATHULATA.

BY LILIAN BUNTON.

Plates XXXVIII to XLV.

TWO excellent representatives of xerophytic vegetation, *Townsendia exscapa* and *Lesquerella spathulata*, were collected in Gove county, Kansas, at an elevation of 2700 feet. These plants are not common throughout this district and are limited to certain localities. *Townsendia* was found growing in draws in the immediate vicinity of the town of Gove and also on the flat, open prairie around "Castle Rock," about twenty-five miles southeast of Gove, and in the vicinity of a group of rocks known as the "Pyramids," thirty miles southwest.

A general idea of the appearance of the vegetation of this district may be derived from figure 1. My examples of *Townsendia*, therefore, were growing on the flat, open prairie as well as in the draws, occurring not in clumps or patches, but as isolated individuals within three or four feet of one another. The plants on the open prairie show a more luxuriant growth than those in the draws.

The specimens of *Lesquerella* were collected about twelve miles southwest of the town of Gove on a rocky, clay bluff. This plant, unlike *Townsendia*, was found growing not as isolated individuals but in rather large colonies.

Of all the ecological factors influencing the structure, habit and distribution of plants the most potent is the water supply. In Gove county the total precipitation for the year 1904 was 18.10 inches; the greatest monthly precipitation was 4.13 inches, in May; the least monthly precipitation was 0 inches in February and November. The total snowfall for the year was 5.5

inches and the number of rainy days 39. In the following table is given the monthly and annual precipitation in Gove county for the year 1904, with departures from the normal:

	Precipitation	Departure
January.	0.01	—0.57
February.	0.00	—0.72
March.	1.00	+0.32
April.	1.79	—0.27
May.	4.13	+0.89
June.	2.62	—1.25
July.	2.18	—1.47
August.	2.57	+1.11
September.	1.26	—1.08
October.	2.00	+0.98
November.	0.00	—0.51
December.	0.55	+0.03
Annual.	18.10	—2.27

From comparisons with other places in Kansas where weather records have been kept, it is seen that the amount of precipitation of this habitat is remarkably small; in fact, being the least, excepting that of Oberlin, Lakin, and Dodge City, where the annual precipitation was 15.72 inches.

One may acquire a general idea of the temperature of this locality from the following tables:

Monthly and annual mean temperature for year 1904, with departure from normal, Fahrenheit.

	Temperature	Departure
January.	29.0	+0.9
February.	30.6	+1.9
March.	43.8	+6.4
April.	48.6	0.0
May.	57.8	—4.6
June.	67.4	—4.9
July.	74.8	—3.8
August.	72.6	—4.0
September.	68.3	—0.1
October.	55.3	+1.5
November.	44.6	—0.9
December.	30.2	—2.4
Annual.	51.9	—0.5

Monthly maximum temperatures for the year 1904, with dates.

January 18	65°	July 29	102°
February 9	72°	August 24	95°
March 2	82°	September 9	103°
April 10	79°	October 3	87°
May 24	93°	November 18	73°
June 23	99°	December 31	68°

Monthly minimum temperatures for year 1904, with dates.

January 25	—2°	July 26	54°
February 19	3°	August 22	50°
March 3	6°	September 14	41°
April 17	25°	October 25	25°
May 14	34°	November 11	11°
June 11	50°	December 26	4°

Another ecological factor which has much to do in shaping plants is the wind. On the prairies the wind has full sweep; it blows most of the time at a rapid rate and tends to dry up whatever vegetation there may be in its path. No definite statement can be made as to the velocity of the wind of this special locality. In the following table, however, are shown some of the results of observations made by Stevenson, of Edinburgh, upon the increase in velocity of the wind with the height above the ground, as given in Schimper's Plant Geography:

Height of instrument aboveground, in feet.	Velocity of wind in miles per hour.
½	6.83
2⅓	8.73
4⅓	9.77
9½	10.45
14	10.54
25	11.54
50	12.21

Height of instrument aboveground, in feet.	Velocity of wind in miles per hour.
½	9.8
3½	12.4
9	13.8
14	14.3
25	15.0
51	16.3

Height of instrument aboveground, in feet.	Velocity of wind in miles per hour.
1⅓	22.2
3½	25.6
9	31.9
14	33.7
25	37.1
51	42.7

From the above tabular statement it is quite clear that plants that are only slightly raised aboveground experience the effects of the wind much less than tall plants, and especially trees.

The action of the wind on plants is partly direct by tensile stresses and partly indirect by increasing transpiration; both these actions are the more energetic the taller the plants or the higher their location.

Where my *Townsendias* occurred the soil is a loose, calcareous deposit, allowing the water quickly to percolate through it.

When the character of its habitat is considered, it would be expected that the anatomy of *Townsendia* must be that of a xerophyte.

TOWNSENDIA EXSCAPA.

Townsendia exscapa is perennial from a woody taproot which averages ten centimeters long and three to four millimeters in diameter at the thickest portion. The stem grows from one to four inches high. The fact that this plant is low helps it to endure the strong winds prevailing in its locality.

The character of the stem varies in different plants. In some, while young, it is quite simple, bearing only a few heads of flowers; in others it is several-branched, bearing six or more heads. As a rule, however, it gradually becomes more and more branched with age until the whole plant may attain a breadth of ten to twelve inches, bearing about 100 heads of flowers. The leaves are all clustered at the base, narrowly linear or slightly spatulate, and one to two inches long. The flowers are white and are borne in sessile heads one to one and one-half inches broad. In figure 2 is shown a photograph of *Townsendia*. When the flowers of the larger plants have gone to seed the plants have the appearance seen in figure 3.

In the discussion of the histology of *Townsendia* the stem will be first treated, then the root, and last the leaf, and the different tissue systems under each will be examined.

The Stem.

Tegumentary Tissues.—The protection of the mature stem is provided for by a cutinized epidermis and cork tissue. All the walls of the epidermis are cutinized. In figure 4 is shown a small portion of the cutinized epidermis. In the following table is given the average thickness of the walls of the epidermal cells and the average length and width of the cavity of the epidermal cells of *Townsendia* and a few mesophytes and xerophytes:

		Outer wall.	Inner wall.	Radial wall.	Vertical length.	Radial width.
MESOPHYTES.	Eupatorium altissimum.	0.005 mm.	0.001 mm.	0.001 mm.	0.022 mm.	0.015 mm.
	Salvia azurea.	0.006 mm. Cutinized. portion, 0.005 mm. Cuticle, 0.001 mm.	0.006 mm.	0.003 mm.	0.02 mm.	0.01 mm.
HYDROPHTES.	Sagittaria.	0.003 mm.	0.001 mm.	0.001 mm.	0.02 mm.	0.01 mm.
	Nelumbo-lutia.	0.006 mm.	0.003 mm	0.003 mm.	0.04 mm.	0.02 mm.
TOWNSENDIA.	....	0.05 mm.	0.02 mm.	0.018 mm.	0.09 mm.	0.068 mm.

In the following table is given the average thickness of the layer of cork, the average thickness of the walls of the cork cells, and the average length and width of the cell cavity in *Townsendia:*

Thickness of cork......................	4-7 cells.
Average thickness of wall..............	0.004 mm.
Average length of cavity...............	0.14 mm.
Average width of cavity................	0.087 mm.

In figure 5 is shown a small portion of cork tissue in cross section.

When compared with the mesophytes and hydrophytes above mentioned, it is seen that *Townsendia* has a well developed protective system, one of the primary requisites of a plant growing in a dry, windy habitat.

The Strengthening Tissues.—The strengthening tissues found in *Townsendia* consist exclusively of collenchyma and short sclerenchyma cells. From figures 6 and 7, collenchyma cells as seen in cross and longitudinal sections, it may be seen that the cells of the collenchyma tissue have remarkably thick walls. The walls of the short sclerenchyma cells also are much thickened, as shown in figures 8 and 9. No true bast fibers are found; the tissue that in cross section appeared to be bast when examined longitudinally proved not to be bast, but a tissue of short sclerenchyma cells. Wood fibers are also wholly lacking. This deficiency, however, is in a measure compensated by the modification of other tissues, the walls of the wood parenchyma, cortex, pith and medullary-ray cells being remarkably thickened. The walls of the cortex and pith cells are, on the average, 0.03 mm. thick. In figures 10 and 11 are shown a few cortex cells as seen in cross and longitudinal sections, respectively. In figures 12 and 13 are shown a few pith cells as seen in cross and longitudinal sections, respectively. As shown in figure 14, the tracheids have thick, lignified walls and constitute the smaller portion of the xylem area; these, together with the wood parenchyma cells, tend to strengthen the plant. A longitudinal section was mounted in a drop of concentrated solution of chromic acid; in a few minutes everything had disappeared but the tracheids. The chromic acid dissolved the wood parenchyma cells, leaving the tracheids isolated as shown in figure 15. The average length of a tracheid is 0.243 mm.; the average width, 0.016. mm.

Tracheal Tissues.—In the stem the conduction of water is provided for by tracheids varying in length, and in longitudinal section having the appearance of typical tracheal tubes. When, however, a longitudinal section was macerated under a cover glass in chromic acid, the tracheids were isolated from the other tissues and stood out prominently as spiral and scalariform tracheids. By computing the number of tracheids in one xylem wedge and multiplying by the number of such wedges, where the cross section of the stem is 19.635 sq. mm. in area, there were found to be 1313 tracheids. The average diameter of these stem tracheids is 0.016 mm. The total water-conducting area of the stem, cross section, is 0.266 sq. mm., which is 1.3 per cent of the whole stem. Of the xylem portion of the stem, 6.6 per cent is given up to tracheids.

When compared with the water-conducting tissue of several mesophytic herbaceous plants, that of *Townsendia* seems quite small. In *Saponaria officinalis* 22.7 per cent of the whole stem is devoted to the conduction of water; of the xylem portion 29 per cent, the average diameter of a tracheal tube being 0.026 mm. Thus it is seen that 17 times as much of the stem of *S. officinalis* as in *Townsendia* is devoted to the conduction of water.

In *Verbena stricta* there was devoted to the conduction of water 9 per cent of the stem cross section, where the area was found to be 3.801 sq. mm. Of the xylem portion, 62 per cent was devoted to the conduction of water. In *Verbena*, then, there was found devoted to the conduction of water seven times as much of the stem as in *Townsendia*. In *Mentzelia oligosperma* there was devoted to the conduction of water 9 per cent of the stem cross section, where the area was 9.07 sq. mm. Of the xylem portion, 33 per cent was devoted to the conduction of water. In *Mentzelia* also there was found to be devoted to the conduction of water nearly seven times as much of the stem as in *Townsendia*. In *Ambrosia artemisifolia* there was found devoted to the conduction of water 21 per cent of the stem cross section, where the area was 13.86 sq. mm. Of the xylem portion 52 per cent was devoted to the conduction of water. In *Ambrosia*, then, there was devoted to the conduction of water about sixteen times as much of the stem as in *Townsendia*. In *Abutilon avicennæ* there was devoted to the conduction of water 2 per cent of the stem cross section, where the area was 38.48 sq. mm. Of the xylem portion, 6 per cent was devoted to the conduction of water. In *Abutilon*, accordingly, there was devoted to the conduction of water approximately twice as much of the stem as in *Townsendia*.

When compared with the water-conducting tissues of desert plants, which have have been discussed by W. A. Cannon[1] in his paper on the "Water-conducting Systems of Desert Plants," *Townsendia* has a relatively large water-conducting area.

In the following table is given the number of tracheal elements in 1 sq. mm. of stem, cross section, of *Townsendia*, and of several mesophytes and xerophytes; the latter cited from Cannon:

Townsendia	66
Mesophytes:	
Abutilon avicennæ	33
Verbena stricta	734
Mentzelia oligosperma	77
Ambrosia artemisifolia	124
Xerophytes:	
Celtis pallida	1
Covillea tridentia	2
Fouquieria splendens	7

Tissues for Food Conduction and Storage.—The medullary ray is composed of two kinds of cells, some with rather thick cellulose walls which measure 0.001 mm. in thickness. The thick-walled medullary-ray cells constitute approximately one-third of the whole area of a medullary ray. An explanation of there being both thick- and thin-walled medullary-ray cells may possibly be that the thick-walled cells have sacrificed their function of conduction and have assumed that of strengthening. The average vertical length of a medullary-ray cell is 0.01 mm.; the average width 0.008 mm. In figure 16 are shown a few medullary cells as seen in cross section; in figure 17 as seen in longitudinal section.

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[1] Bot. Gazette, June, 1905, pp. 396-408.

Very little special provision for the passage of food longitudinally seems to have been made by *Townsendia.* The ordinary collateral vascular bundles are found. A comparatively small portion of the vascular bundle, however, is devoted to phloëm—about 12 per cent; in *Verbena stricta* 25 per cent of the vascular bundle is devoted to phloëm. In *Mentzelia oligosperma* there is the same proportion of the vascular bundle devoted to phloëm as in *Townsendia*—12 per cent. Neither sieve tubes nor sieve parenchyma cells are found in *Townsendia.* The whole work of conduction of food longitudinally is apparently assumed by the cambiform cells and the undivided mother cells of the sieve tubes. Presumably the sieve tubes, when present in a plant, would carry the food more rapidly. The most elaborated sieve tubes are always found in plants of considerable length, especially in trailing, clambering and climbing plants. *Townsendia,* however, is so low that it seems that the food can be conducted longitudinally rapidly enough and in sufficient quantities by the cambiform and undivided mother cells of the sieve tubes without the aid of sieve tubes.

In figure 18 are shown phloëm cells as seen in cross section; in figure 19, as seen in longitudinal section: *a,* cambiform cell; *b,* undivided mother cell of the sieve tubes. The average length of these cells is 0.18 mm; the average width, 0.01 mm. The average thickness of their cell wall is 0.0006 mm.

In *Townsendia,* the xylem parenchyma cells and the medullary ray, cortex and pith cells afford sufficient means for the storage of food. Upon examination of sections of the stem of the plant collected at the time of flowering and fruiting, there appeared stored up in the tissues of the stem no food whatever, thus showing that the food must at this time be used by *Townsendia* as fast as it is made. No statement, however, can be made of the storage of food in the plant later in the season.

The Root.

Tracheal Tissues.—As in the stem, the conduction of water in the root is provided for by spiral and scalariform tracheids. By computing the number of tracheids in a certain portion of a cross section, and multiplying by the number of such portions, there were found to be 1271 tracheids in the cross section of the root. In figure 20 may be seen how these tracheids are distributed throughout the section. The average diameter of these tracheids is 0.018 mm. The total water-conducting area in a root, where the cross section area is 7.496 sq. mm., is 0.325 sq. mm., or 4.2 per cent of the whole root area.

In structure, the other tissues of the root do not differ essentially from those of the stem; hence the discussion of them as found in the stem will suffice for the root.

The Leaf.

The Tegumentary Tissues.—The outer wall of the epidermis of the leaf is not wholly cutinized; the inner portion is of cellulose and is 0.0108 mm. thick, and the outer portion of the wall is cutinized and is 0.0072 mm. thick. The inner tangential wall is of cellulose and is 0.0036 mm. thick. The radial walls are likewise of cellulose and 0.0036 mm. thick. The average tangential length of the cells of the epidermis is 0.0396 mm.; the average radial length, 0.025 mm. No difference was found between the upper and lower epidermis, hence the figures given above will suffice for both. In figure 24 is shown a portion of the cutinized epidermis as seen in cross section.

Tracheal Tissues.—After a leaf boiled in alcohol had remained in a mixture of chloral hydrate and hydrogen peroxide for several days, it had become so well bleached that its venation could be seen easily with the naked eye. There appeared three prominent longitudinal veins, one central and two lateral, from which extended other veins branching in every direction and terminating in water-storage tracheids, as shown in figure 21*a*. In the cross section of the midrib through the center of the leaf were found ninety-five tracheids, the average diameter of which was 0.0075 mm., making the total water-conducting area there 0.00004 sq. mm. The cross-section area of the midrib was 0.01207 sq. mm., 32 per cent of which was devoted to conduction of water. In figure 21*b* is shown the midrib as seen in cross section. In the cross section of each of the lateral veins were found twenty-eight tracheids, the average diameter of which was 0.0059 mm., making the total water-conducting area in each vein 0.00073 sq. mm. The total cross-section area of each vein was 0.003 sq. mm., 24 per cent of which was devoted to the conduction of water. The average distance between the ultimate branches of the veins—*a* and *b*, figure 22—is 0.031 mm.

In the leaf, the phloëm consists only of cambiform cells and undivided mother cells of the sieve tubes; the xylem is made up of wood parenchyma cells and spiral and scalariform tracheids. The average diameter of the cavity of the tracheids is 0.006 mm. The walls of the parenchyma cells, however, remain quite thin. In figure 23 are shown the phloëm cells as seen in longitudinal section of the midrib: *a*, cambiform cell; *b*, undivided mother cell of the sieve tubes. The average length of these cells is 0.14 mm., the average width 0.01 mm., the average thickness of the cell wall 0.0006 mm.

The Photosynthetic Tissues.—On both sides of the leaf are found palisade cells; the spongy parenchyma cells are not very prominent and towards the center of the leaf, in some places in the leaf not really being differentiated from the palisade cells. The explanation of the palisade cells on both sides of *Townsendia* may be that out on the open prairie the reflected light from below is sufficiently intense to stimulate the formation of palisade tissue on the under side of the leaf.

On each side of the leaf there are from two to three layers of palisade cells, the average length of which is 0.14 mm., the average width 0.05 mm. The average number of chloroplasts in a single cell is twenty-nine and the average diameter of a chloroplast is 0.0008 mm. In figure 25 are shown the palisade cells as they appear in surface view; in figure 26 spongy parenchyma cells as they appear in surface view.

In the following table is shown the number of chloroplasts found in a single mesophyll cell of a number of plants, as given in Haberlant's "Pflanzen-Anatomie":

	Palisade cells.	Spongy parench. cells.
Fragaria elatior	86	14
Pulmonaria officinalis	85	15
Ricinus communis	82	18
Brassica rapa	80	20
Galeopsis tetrahit	79	21
Fropaeolum majus	77	23
Helianthus annuus	73	27
Phaseolus multiflorus	69	31
Bellis perennis	67	33

When compared with the plants above mentioned, it is seen that in the leaf of *Townsendia* the chloroplastic surface is relatively small. On both sides of the leaf the number of chloroplasts in a single mesophyll cell is approximately twenty-nine, thus giving to both sides of the leaf the same chlorophyll-producing volume. The small number of chloroplasts found in the mesophyll cells of the upper side allows the sunlight to penetrate to the lower side of the leaf, thus giving to the cells there the power to carry on photosynthesis more effectively.

The Water-storage Tissues.—In the leaf of *Townsendia* there is an admirable arrangement for all the mesophyll cells to have immediate access to water. Throughout the full length of the leaf on both sides are found large cells which are used primarily for the storage of water. These water-storage cells, however, seem to assume other functions; they evidently take part in the conduction of water and aid to a slight degree in photosynthesis. They have very thin walls, which are lined by a few chloroplasts much smaller than those found in the other mesophyll cells. Bordering on these water-storage cells are mesophyll cells which draw upon them for water when there is need.

In order to secure the greatest access to water the palisade cells occur in various relations: bordering on veins, on water-storage cells, on spongy parenchyma cells. In the following table is shown the relative frequency of palisade cells bordering respectively on water-storage cells, veins and spongy parenchyma cells:

Bordering on water-storage cells	222
Bordering on veins	81
Bordering on spongy parenchyma cells	42

From the above figures it is seen that the palisade cells occur most frequently bordering on the water-storage cells, there being nearly three times as many bordering on the water-storage cells as on the veins and twice as many bordering on the veins as on the spongy parenchyma cells. Figure 27 is a diagrammatic drawing, showing the distribution of water-storage cells, *b*, as seen in a cross section of a leaf. In figure 28 are shown the palisade cells, *B*, bordering on water-storage cells, *A*. In figure 29 are shown the palisade cells, *A*, bordering on the veins, *C*. Some places in the leaf the palisade cells, *D*, have still greater access to water, bordering as they do on both water-storage cells, *A*, and storage tracheids, *C*. This relation generally occurs at the ends of the leaf. In figure 30 are shown the palisade cells as found in this relation. Sometimes the palisade cells are found bordering on water-storage cells, *A*, which in turn border on veins, *C*, as shown in figure 31. Such an arrangement as this is an excellent one; for as fast as the water-storage cells are deprived of the supply of water on hand they can immediately draw on the veins and thereby continue to supply the palisade cells with water as it is needed. In figure 32 are shown palisade cells, *A*, bordering on spongy parenchyma cells, *B*.

Another means for storage of water is the water-storage tracheids found at the termination of the veins. Palisade cells bordering on these tracheids can obtain water when there is need. In figure 33 are shown these tracheids as they appear at the ultimate ends of the veins; in figure 34 the water-storage tracheids as they appear in other places in the leaf.

The Aërating Spaces.—In *Townsendia* there were found devoted to aëration only 20 sq. mm. of the surface of a leaf which measured 100 sq. mm.; or, in other words, the volume of the intercellular spaces and the volume of the whole leaf, roughly estimated, stand in the relation to each other as 8:1000. When compared with *Pistia texensis*, an hydrophyte, whose aërating volume and the volume of the whole leaf stand in the relation to each other as 760:1000, the amount of volume devoted to aëration in *Townsendia* seems quite small.

There were found on either side of the leaf an approximate average of 344 stomata to 1 sq. mm., the average number usually found in plants. There was no difference in the character of the stomata on either side of the leaf. It seems rather surprising to find in the leaf of a xerophyte the usual number of stomata found in plants and to find them at the surface of the leaf instead of being sunken beneath the epidermis; for, as a rule, in xerophytic plants there are fewer stomata and they are often sunken beneath the epidermis.

In figure 35 are shown the stomata as they appear in the surface view of the leaf of *Townsendia*. In figure 36 is shown a stoma as it appears in cross section of the leaf.

SUMMARY.

1. *Size and Habit of Townsendia.*—*Townsendia* is a low plant, growing from one to four inches high; it grows on the flat, open prairie as well as in the draws, and occurs not in clumps but as isolated individuals. The stem is at first relatively simple, but, as a rule, it becomes more and more branched with age until the whole plant may attain a breadth of ten to twelve inches.

2. *Tegumentary Tissues.*—In the mature stem of *Townsendia* the cutinized epidermis, whose outer walls measure 0.05 mm., and the cork tissue several layers thick, constitute the tegumentary tissues.

In the leaf of *Townsendia* there is found an epidermis whose outer wall measures 0.017 mm. in thickness. The outer portion of the wall is cutinized and measures 0.0072 mm. in thickness; the inner portion is of cellulose and measures 0.0108 mm. in thickness.

3. *Strengthening Tissues.*—In *Townsendia* the strengthening tissues of the stem consist of collenchyma and short sclerenchyma cells. True bast fibers and wood fibers are lacking. The remarkably thick cell walls, not only of the strengthening tissues but of nearly all the tissues, make the stem of *Townsendia* strong.

4. *Tracheal Tissues.*—The area devoted to conduction of water in *Townsendia* is comparatively small, there being only 1.3 per cent of the stem devoted to that function. Growing as it does in a location where the water supply is poor, *Townsendia* would not require very extensive water-conducting tissues.

5. *Food-conducting Tissues.*—Longitudinally there seems to have been made very little provision for the conduction of

food in the stem. The phloëm portion is very little differentiated; it consists only of cambiform cells and undivided mother cells of the sieve tubes, there being found neither sieve tubes nor sieve parenchyma cells.

6. *Storage Tissues.*—Since *Townsendia* grows in a xerophytic habitat it is not surprising to find in it some provision for the storage of water. In the stem, the cortex, medullary ray and pith cells are well adapted to the storing of water. In the leaf, however, special provision is made: throughout the whole length of the leaf are found large water-storage cells which not only reduce transpiration but also rapidly fill whenever the water supply is increased, and yield their contents to the assimilating cells as the supply of water there is reduced.

7. *Aërating Spaces.*—As would be expected to be found in a xerophyte, the amount of space devoted to aëration is comparatively small. Only one one hundred and twenty-fifth of the volume of the leaf of *Townsendia* is devoted to aëration; while in *Pistia* about two-thirds of the volume of the leaf is thus employed.

LESQUERELLA SPATULATA.

Lesquerella spatulata is perennial by a much branched caudex which varies from one to two inches in length. It has a taproot which measures from one foot to a foot and a half in length and one-fifth of an inch in diameter at its thickest portion. The leaves are separated by short internodes and appear tufted. They measure from one-half to one inch in length and one-fifth to one-seventh of an inch in width. They are entire and vary in form from narrowly elliptic to ovate-lanceolate, oblanceolate and spatulate, and they, as well as the pedicels, are beset with stellate hairs. The flowers are yellow and are borne on pubescent scapes which measure from one-half inch to six inches in length.

The Stem.

The Tegumentary Tissues.—The protection of the mature stem is provided for by a cutinized epidermis and cork. There is, in addition to these tissues, in older portions of the stem, a borke. All of the walls of the epidermis are cutinized. Figure 37 represents a small portion of the epidermis as seen in cross section; figure 38*a*, a small portion of the epidermis as seen in longitudinal section.

In the following table is given the average thickness of the cell walls and the average length and width of the epidermal cells:

Outer tangential wall	0.0049 mm.
Inner tangential wall	0.0049
Radial wall	0.003
Vertical diameter of cavity	0.075
Radial diameter of cavity	0.026
Tangential diameter of cavity	0.04

In the following table is given the average radial breadth of the cork zone, the average thickness of the walls of the cork cells, and the vertical, radial, and tangential dimensions of the cell cavity:

Average breadth cork zone	15-20 cells.
Average thickness of wall	0.001 mm.
Vertical diameter of cavity	0.025
Radial diameter of cavity	0.026
Tangential diameter of cavity	0.036

Figure 38*b* represents a few cork cells as seen in cross section.

In addition to this large zone of cork there are found in the borke rather large stone cells, which, as shown in figure 39, have relatively thick and pitted walls.

The tegumentary tissues are remarkably well developed for such a low, herbaceus plant as *Lesquerella*. When, however, its xerophytic habitat is taken into consideration, the necessity for this provision is readily seen.

The Strengthening Tissues.—The strengthening tissues in the stem consist of collenchyma, bast fibers, stone cells and wood fibers.

The radial breadth of the collenchyma zone is 0.093 mm. The average thickness of the walls of the collenchyma cells is 0.006 mm.; the average tangential breadth of the cell cavity is 0.036 mm.; the average radial thickness is 0.01 mm. In figure 40 are shown a few collenchyma cells as seen in cross section; in figure 41 as seen in longitudinal section.

The sclerenchyma tissue is made up of cells which vary from stone cells to short bast fibers. As shown in figure 42, the stone cells found here are smaller than those found in the borke. Figure 43 represents the stone cells as they appear in longitudinal section.

The bast fibers are 0.11 mm. long and 0.016 mm. wide, the average thickness of the cell wall being 0.006 mm. As may be seen in figure 44, the ends of the fibers overlap but little. In figure 45 are shown a few bast fibers as seen in cross section.

The most striking characteristic of the strengthening tissues of the stem is the presence of large zones of thick-walled wood fibers, which constitute 26 per cent of the area of the stem and 78 per cent of the area of the xylem. These wood fibers, as shown in figure 46, occur among spiral tracheal tissues. They average 0.11 mm. in length and 0.01 mm. in width. The walls are remarkably thick—0.006 mm.; the cell cavity is exceedingly small, in some places being almost entirely obliterated. Figure 47 represents a wood fiber as seen in longitudinal section.

The strengthening system in the stem of *Lesquerella* is more extensively developed than that in the stem of *Townsendia,* the only strengthening tissues found in the stem of *Townsendia* being collenchyma and short sclerenchyma cells, bast fibers and wood fibers being absent. This deficiency in *Townsendia,* however, is compensated by remarkably thick cell walls, not only of the strengthening tissues but of nearly all the tissues. The strengthening tissues in the stem of *Lesquerella* are so well developed that there is no need of the other tissues being modified, as was the case in the stem of *Townsendia.*

The Tracheal Tissues.—The tracheal system in the stem of *Lesquerella* consists of spiral and scalariform tracheal tubes and spiral and scalariform tracheids alone. There was found devoted to the conduction of water 2 per cent of the stem cross section, where the area was 7 sq. mm.; 4 per cent of the xylem, where the cross section area was 3.46 sq. mm., was devoted to this purpose.

In the following table is given the average thickness of the cell wall, and the average tangential and radial dimensions of the cell cavities of the various tracheal elements found in the stem of *Lesquerella*:

	Average thickness of cell wall.	Radial diameter of cavities.	Tangential diameter of cavities.
Largest tracheal tubes	0.002 mm.	0.016 mm.	....
Smallest tracheal tubes	0.003	0.002	....
Tracheids	0.002	0.016	0.04 mm.

As shown in figure 46—a small portion of the xylem as seen in cross section—the tracheal elements occur among alternating, definite zones of wood fibers, *A*, and wood parenchyma cells, *B*, the largest ones being among the wood fibers and the smallest among wood parenchyma cells. It is generally conceded that spiral vessels are formed by the procambium exclusively, and wood fibers by the cambium. As the tracheal elements found interspersed among the wood fibers are spiral and scalariform, the activity here must be due either to the cambium or procambium. From the fact that these spiral vessels are found somewhat remote from the pith, there follows a probable conclusion that the cambium, contrary to the general rule, has formed spiral vessels.

The tracheal elements found in the stem at the nodes were different from those in the internodes. At the nodes the tracheal tissues consist exclusively of short and peculiarly shaped tracheids. In figure 48, *A*, are shown the scalariform type of tracheids; *B*, the spiral type of tracheids as seen in longitudinal section.

In the internodes the tracheal elements consist exclusively of spiral and pitted tracheal tubes, with the exception of a few tracheids interspersed here and there. Figure 49, *A*, illustrates the spiral tracheal tubes found among the wood fibers, as seen in longitudinal section; figure 49, *B*, spiral tracheal tube found among the wood parenchyma cells; figure 49, *C*, pitted tracheal tubes as seen in longitudinal section.

Tissues for the Conduction and Storage of Food.—The medullary rays found in the stem of *Lesquerella* present an interesting characteristic. Throughout the entire length of the medullary ray are found leaf traces containing spiral tracheal tubes as shown in figure 51, *a*. These tracheal tubes are much smaller than those found in the xylem area of the stem, the average diameter of the cavity being 0.007 mm. and the average thickness of the cell wall 0.002 mm. Figure 50, *a* represents a leaf trace. The internodes are so short that it is impossible to cut a section without having leaf traces traversing the medullary rays. These leaf traces run horizontally into the primary xylem, and when the cambium begins its activity it builds up the medullary rays around them. The average width of a medullary ray is 0.06 mm., and the average vertical length of a medullary-ray cell is 0.03 mm., and its average width is 0.01 mm. Figure 51, *b* represents a small portion of the medullary ray as seen in cross section.

In the stem, the ordinary collateral vascular bundles are found; 20 per cent of the vascular bundle is devoted to phloëm, as in *Townsendia.* Neither seive tubes nor seive parenchyma cells are found. The whole work of conduction is assumed by the undivided mother cells of the sieve tubes. *Lesquerella* is a very low plant and it seems that the food can be conducted longitudinally fast enough and in sufficient quantities without the aid of the other phloëm elements. In figure 51, *c,* are shown a few phloëm cells as seen in cross section; in figure 52, as seen in longitudinal section; at the angles of these cells occur small intercellular spaces, *A.*

In the stem of *Lesquerella* the storage of food is provided for by means of the thin-walled parenchyma of the cortex and the xylem parenchyma and the medullary rays. Figure 53 represents a few cells of the thin-walled parenchyma of the cortex as seen in cross section. Figure 54 represents a few cells of the xylem parenchyma as seen in longitudinal section. In all of these tissues starch and proteid were found in small quantities, but neither sugar nor oil.

Figure 50 is a diagrammatic drawing of the cross section of the stem traced as seen when projected upon a screen. From this may be derived a general idea of the various tissues of the stem, their relation to one another, and the proportion of the stem devoted to each: *A,* borke; *B,* collenchyma; *C,* sclerenchyma; *D,* phloëm; *E,* xylem; 1, tracheal tissues; 2, wood fibers; 3, xylem parenchyma; *F,* medullary ray; *a,* leaf-trace.

The Root.

The Tegumentary Tissues.—The tegumentary tissues of the mature root consist of a cutinized epidermis and cork tissue which are similar to those tissues found in the stem, both in structure and proportion.

The Strengthening Tissues.—The strengthening tissues found in the root of *Lesquerella* consist of collenchyma, stone cells and wood fibers. These tissues show no difference whatever from those found in the stem.

The Tracheal Tissues.—The tracheal tissues in the root consist entirely of scalariform and spiral tracheal tubes. In a root where the cross section area was 18.75 sq. mm., there was found devoted to the conduction of water 4 per cent. Here the cross-section area of the xylem is 6.7 per cent of the entire root.

In the following table is given the average diameter and the average thickness of the cell walls of the tracheal elements in the root:

Average diameter of the larger tracheal tubes	0.03	mm.
Average diameter of the smaller tracheal tubes	0.007	
Average thickness of cell wall	0.005	

As in the stem the tracheal elements of the root are interspersed among definite, alternating layers of wood fibers and wood parenchyma cells. Figure 55 represents a few wood fibers and tracheal tubes as found in the outermost layer of xylem (fig. 56*a*, *E*) as seen in cross section. Here the tracheal tubes are relatively large and the wood fibers have comparatively large cavities. The next succeeding layer of xylem (fig. 56*a*, *F*) consists of very small, thick-walled tracheal tubes, *A*, and wood parenchyma cells, *B*, shown with greater magnification in figure 57. In figure 58 are shown a few wood parenchyma cells as seen in longitudinal section. The average length of these cells is 0.07 mm. and the average width 0.015 mm. Figure 59 represents a few wood fibers and tracheal tubes found in the next succeeding layer of xylem (fig. 56*a*, *G*). The average diameter of the tracheal tubes in this layer of xylem is 0.023 mm.; here the wood fibers have remarkably thickened walls and a smaller cavity than those found in the outermost layer of xylem (fig. 56*a*, *E*).

Figure 56*a*, a segment of the cross section of the root, shows the constitution of the xylem: *A*, wood fibers; *B*, tracheal elements; *C*, wood parenchyma.

In figure 56*b* are shown the tracheal elements found in the root: *A* and *B*, scalariform tracheal tubes, *C*, spiral tracheal tube.

Tissues for the Conduction and Storage of Food.—In the root are found only secondary medullary rays, which are narrower than those found in the stem. In these medullary rays is found no tracheal system as in those of the stem. As in the stem, there seems to have been made very little provision for the passage of food longitudinally. Yet, however, a larger proportion (25 per cent) of the vascular bundle of the root is devoted to phloëm than in the stem. The phloëm consists exclusively of undivided mother cells of the sieve tubes.

Starch and proteids in small quantities were found in the medullary rays and phloëm-parenchyma cells, but neither glucose nor oil. In the root of *Townsendia* there was found glucose, but neither starch, proteid nor oil.

In figure 60—a diagrammatic drawing of the cross section of the root traced as seen when projected upon a screen—are shown the different zones of tissues of which the root consists and their relation to one another: *A*, cork; *B*, collenchyma; *C*, stone cells; *D*, thin-walled parenchyma; *E*, phloëm; *F*, wood fibers; *G*, wood parenchyma; *H*, tracheal elements; *I*, medullary ray.

The Tegumentary Tissues.—The tegumentary tissues consist of an epidermis with trichomes. All the walls of the epidermis are cellulose except the outer tangential wall, which has a thin film of cutin on the outer portion. The outer and inner tangential wall each measures in thickness 0.006 mm., and the radial wall 0.003 mm. The average radial diameter of the cell cavity is 0.02 mm., the average tangential diameter 0.016 mm. On both sides of the leaf the epidermis is of the same character. Figure 61 represents a small portion of the epidermis: *a*, cutinized portion; *b*, cellulose portion. The trichomes are thickly distributed over both sides of the leaf, and must be quite effective in giving protection. The discussion of these trichomes will be taken up in connection with the water-storage system.

The Tracheal Tissues.—For the study of venation, a leaf was used which had been bleached by standing four or five hours in dilute hydrochloric acid and then two or three days in chloral hydrate. As shown in figure 62, there could be seen in this leaf one large central vein, *A*, running longitudinally throughout the length of the leaf and sending off near the center of the leaf two large lateral branches, *B*, and below the center the large branch, *G*. On either side of the midrib there are two prominent longitudinal veins, *C*. These primary veins send out other veins which branch in every direction and end abruptly, as shown at *D*. The average distance between the ultimate branches of the veins, *E* and *F*, is 0.16 mm., there being included within this area, on the average, twenty-five mesophyll cells. The phloëm consists only of undivided mother cells of the sieve tubes, whose average length is 0.16 mm. and width 0.006 mm. The xylem consists exclusively of spiral tracheary tracheids. The average diameter of the tracheids in the midrib is 0.006 mm., and the average diameter of those in the smaller veins is 0.003 mm. In the midrib, where the cross-section area is 0.015 sq. mm., 20 per cent is devoted to the conduction of water. Figure 63 represents a small portion of the midrib as seen in longitudinal section: *A*, spiral tracheary tracheid; *B*, undivided mother cell of the sieve tubes.

The Photosynthetic Tissues.—The leaf of *Draba* is bifacial, that is, palisade cells occur on both sides of the leaf, which is from twelve to fifteen layers of cells thick. The average radial length of a palisade cell is 0.027 mm., the average cross diameter 0.02 mm. Figure 64 represents a few palisade cells as seen in surface view.

The average number of chloroplasts in a single mesophyll cell on either side of the leaf is twenty-seven. The small number of chloroplasts found in the mesophyll cells of the upper side of the leaf allows the sunlight to penetrate to the lower side, thus giving to the cells there the power to carry on photosynthesis effectively.

The Water-storage Tissues.—In the leaf of *Lesquerella* there are no water-storage cells as are found in that of *Townsendia.* The only structures in the leaf that might serve principally as water-storage elements are the large trichomes which occur on both sides of the leaf. These trichomes, as shown in figure 65 (surface view) are quite frequent, and are stellate-peltate in form. These, as a rule, are found above a vein, and, since they are alive even on old leaves, they presumably have some active function to perform. Their basal portion is slightly depressed beneath the lower level of the epidermis, and the wall here is cellulose. The remaining portion of the wall of the trichomes is cellulose, except the very outer portion, which is cutinized. The fact that these trichomes occur above the veins and that their basal portion is cellulose-walled seems to point to the conclusion that when there is plenty of water furnished by the veins they absorb water, store it up, and yield it to the mesophyll cells as it is needed. Figure 66 represents a trichome as seen in a leaf cross section: *A*, cutinized portion of a wall of trichome; *B*, cellulose portion of wall of trichome; *C*, mesophyll cells; *D*, tracheids.

The Aërating Spaces of the Leaf.—Mounting the bleached leaf so that it could be looked through from surface to surface, I estimate that approximately 2.7 per cent of the volume of the leaf is devoted to intercellular spaces; in other words, the volume of the intercellular spaces and the volume of the whole leaf, roughly estimated, stand in relation to each other as

27 : 1000. On either side of the leaf are found 640 stomata to 1 sq. mm., a much larger number than was found in the leaf of *Townsendia.* The stomata are at the surface of the leaf instead of being sunken, as is often the case with xerophytes. In figure 67 are shown a few stomata as seen in surface view. In figure 68 is shown a stoma as seen in cross section.

Figure 69 represents a small portion of a leaf as seen in cross section: *A*, upper epidermis; *B*, lower epidermis; *C*, palisade tissue; *D*, vascular bundle.

SUMMARY.

1. *Size and Habit of Lesquerella spathulata.*—*Lesquerella spathulata*, a perennial from a branched caudex, is a low plant growing from one to two inches high. It was found growing on a rocky clay bluff, occurring not as isolated individuals, but in colonies.

2. *Tegumentary Tissues.*—In the mature stem of *Lesquerella* the tegumentary tissues consist of a cutinized epidermis, cork, and borke. In the mature root the tegumentary tissues consist of a cutinized epidermis and cork.

The tegumentary tissues of the leaf consist of an epidermis, all the walls of which are cellulose except a thin film of cutin on the outer tangential wall. There is, in addition to the ordinary epidermal cells, stellate trichomes on both sides of the leaf, which would be effective in protection against too intense illumination and in the reduction of transpiration, as well as in the storage of water.

3. *The Strengthening Tissues.*—The strengthening tissues consist of collenchyma, bast fibers, stone cells and wood fibers. The wood fibers constitute a very important part of the strengthening system. These have remarkably thickened walls, the cavities in some cases being almost obliterated. Contrary to the general rule, the wood fibers are found among spiral tracheal tubes, both wood fibers and spiral tracheal tubes having been formed by the cambium.

4. *Tracheal Tissues.*—The tissues devoted to the conduction of water constitute 2 per cent of the stem and 4 per cent of the root. This seems a comparatively small area devoted to this purpose, but growing, as *Lesquerella* does, in a location where the water supply is poor, it would not require very extensive

water-conducting tissues. The tracheal tissues consist of spiral and scalariform tracheal tubes and tracheids.

5. *Photosynthetic Tissues.*—The photosynthetic tissues of the leaf consist exclusively of palisade cells, and there is found in a single palisade cell on either side of the leaf an average of twenty-seven chloroplasts.

6. *Food-conducting Tissues.*—As in *Townsendia,* the phloëm is but little differentiated. It consists exclusively of undivided mother cells of the sieve tubes; sieve tubes and sieve parenchyma cells are wholly lacking.

7. *Storage Tissues.*—In the stem the phloëm cells and medullary-ray cells afford provision for the storage of food. In these tissues starch and proteids were stored up in small quantities. The only storage tissues found in the leaf are the large stellate hairs which, possibly, rapidly fill whenever the water supply is increased, and, being cellulose-walled at their bases, yield their contents to the mesophyll cells as the supply of water is reduced.

8. *Aërating Spaces.*—As would be expected to be found in a xerophyte, the amount of space devoted to aëration is comparatively small, there being only 2.7 per cent of the volume of the leaf devoted to this purpose.

PLATE I.

A. Dakota sandstone resting on Permian shales. Man's head in line with contact. Spring creek, six miles north of Washington.

B. Unconformity of Pleistocene on Permian. Ravine running from left to right in Permian shales with thin limestone forming the top crosses a buried gully at right angles to it filled with Pleistocene material, which is etching backward. Note the tipping of the limestone into the old gully (undisturbed by recent erosion). About three miles east of Washington.

PLATE I.

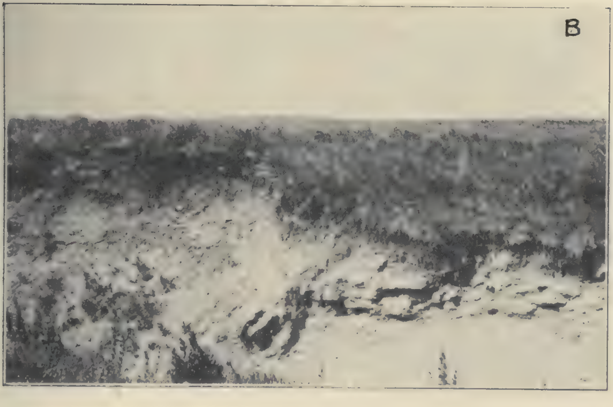

PLATE II.

A. Unconformity of Dakota on Permian sandstone at contact projects. Brickyard, east side of Smoky Hill river, Salina.

B. Same. South end of same hill by old mill.

PLATE II.

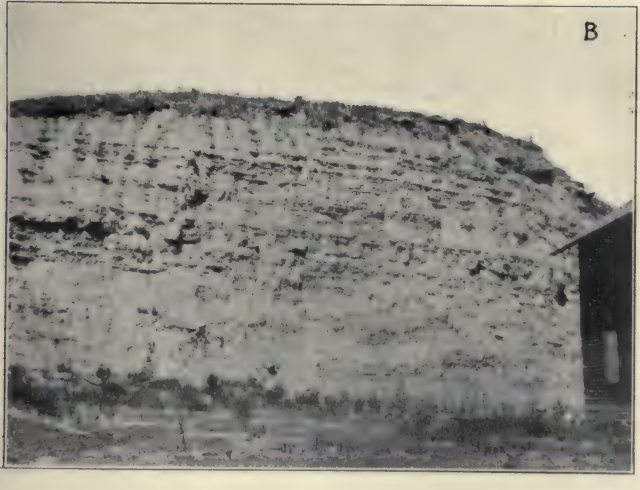

PLATE III.

A. Cliff of Dakota sandstone. East side of Mill creek, northeast of Washington.

B. Slumping of soft sediments, clays apparently of Dakota age. Three miles east of Washington.

A

B

PLATE IV.

A. Slumped soft Dakota clays surrounded by impure sandstone, on Permian floor. Three miles east of Washington.

B. Alfalfa field on the wide terrace of the Republican river, west of Clay Center.

PLATE IV.

PLATE V.

FIG. 1.—View looking southwest from ruins, showing heavy ledges of Loup Fork rock in background, from which the pueblo was built. In the foreground two of the party are shown excavating one of the circular pits which occur about twenty yards north of the main building.

FIG. 2.—Ground plan of ruins, showing remains of the division walls, looking west. Remains of the mealing trough shown in the extreme corner of room I, to the left of the observer. To the right, in room V, the small fireplace built into the wall can be seen.

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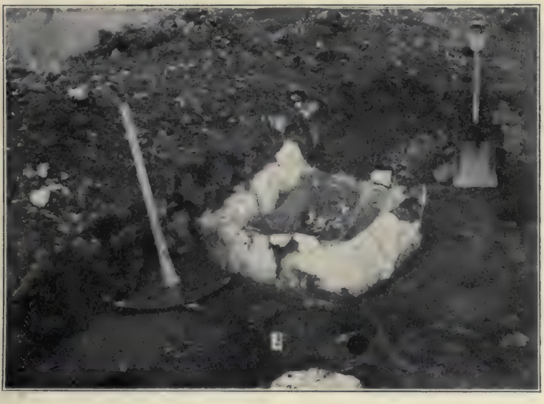
PLATE VI.

FIG. 3.—Typical Pueblo grinding trough, three feet nine inches long by two feet one inch wide and eighteen inches deep.

FIGS. 4, 5, 6, 7.—Awls or drills, used principally for perforating skins and boring holes into bones, etc. Figure 7 is of a reddish flint, beautifully colored, and of fine workmanship.

FIGS. 8, 9, 10, 11, 12.—Bone implements, probably used to enlarge holes in skins. Have been much used.

FIGS. 13 to 18, inclusive.—Pipes and pipe stems; all are made of native clay. Figure 15 is well made and is decorated with the design shown on plate VIII, figure 62; mouthpiece broken off. Pipe measures two and one-half inches long and seven-eighths inch in diameter at the center.



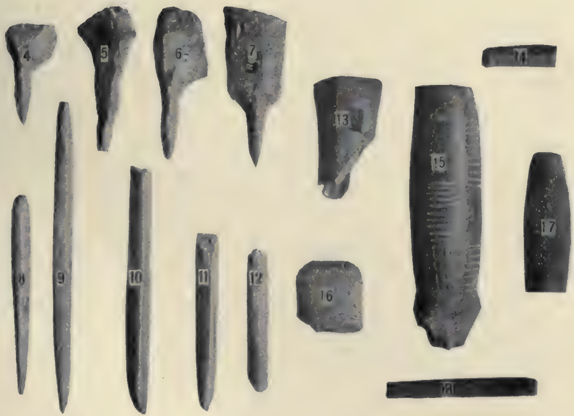

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PLATE VII.

Figs. 19, 20, 21, 22, 23, 24.—Arrow shaft straighteners. These are made of the Dakota sandstone, and probably came from somewhere in the vicinity of Quivira, for no outcroppings of this material are exposed nearer to Quartelejo than those which occur on the western boundary of Brower's Quivira, about 130 miles east of the Quartelejo pueblo.

Fig. 25.—Bone piccolo, made from the wing bone of a large bird, probably a pelican.

Fig. 26.—Bone implement, possibly a hoe blade, from shoulder blade of buffalo.

Fig. 27.—Tallying implement, made from rib of buffalo.

Fig. 28.—Bone tool with a toothed edge, which may have been used for fleshing skins.

Fig. 29.—Bone tool, made from rib of buffalo, worn smooth and flat, spatula-like.

Fig. 30.—Bone implement of undetermined use, much worn, with toothed edge. Made from shoulder blade.

Figs. 43 to 56, inclusive.—Fleshers or scrapers, of flint. Figures 43, 45, 46, 47, 51, 52, are beautifully made. Figures 46 and 51 show cross sections of *Fusilina,* a fossil typical of the Carboniferous. The material of these two, at least, is not found in the vicinity of the ruins, and was probably procured from the eastern part of the state.

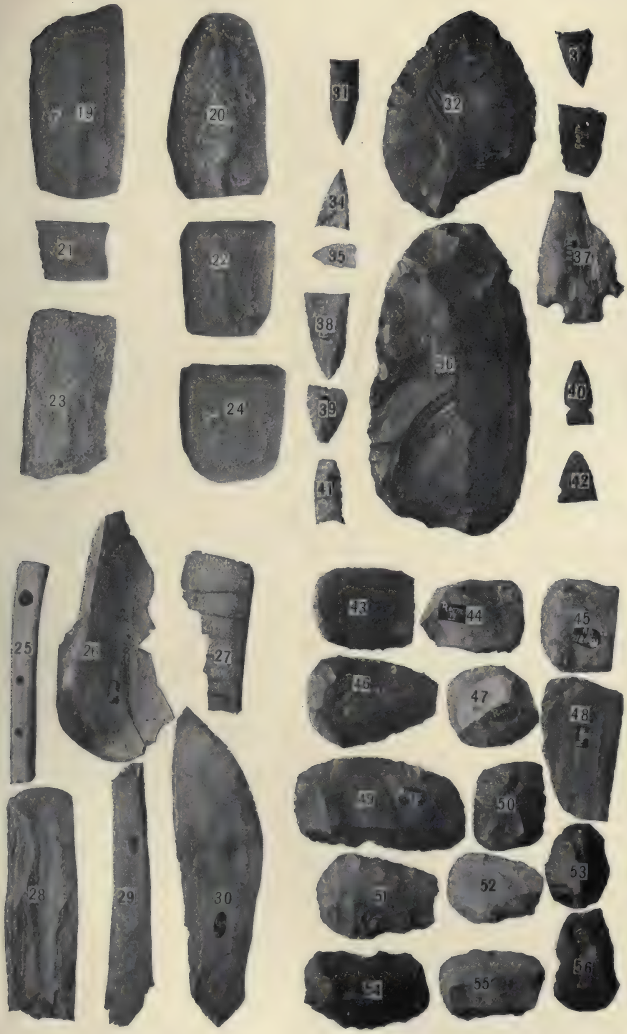
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PLATE VIII.

Figs. 57, 58.—Knife blades of yellow chert.

Fig. 59.—One of the most interesting implements found, consisting of the half of an iron ax head, five and one-half inches long by one and a quarter wide at its greatest width, and five-eighths of an inch thick. This, by some mischance, had been split in two longitudinally, and was arranged with a groove around it instead of an eye like our modern axes have.

Fig. 60.—A fine grinder of conglomerate, eleven inches long. Shows much usage.

Fig. 61.—The half of a clam shell, plainly showing saw-tooth marks where it was divided. This was found at the bottom of the twelve-inch hole in room V.

Fig. 62.—Diagram of pattern on pipe bowl shown on plate VI, figure 15. Impression was made on clay and photographed.

Fig. 63.—Base of deer antler, which has evidently been used as some implement.

Figs. 64 to 69, inclusive.—Specimens of charred corncobs. Figure 59 shows some well-developed kernels on it.

Fig. 70.—Bone implement, well worn.

Fig. 71.—Portion of 'dobe plastering from walls, showing impressions of finger tips.

Fig. 72.—Baked clay marble, evidently used in some game.

Figs. 73, 74, 75.—Chert scrapers.

Fig. 76.—Hoe blade made from shoulder blade of buffalo.

PLATE VIII.

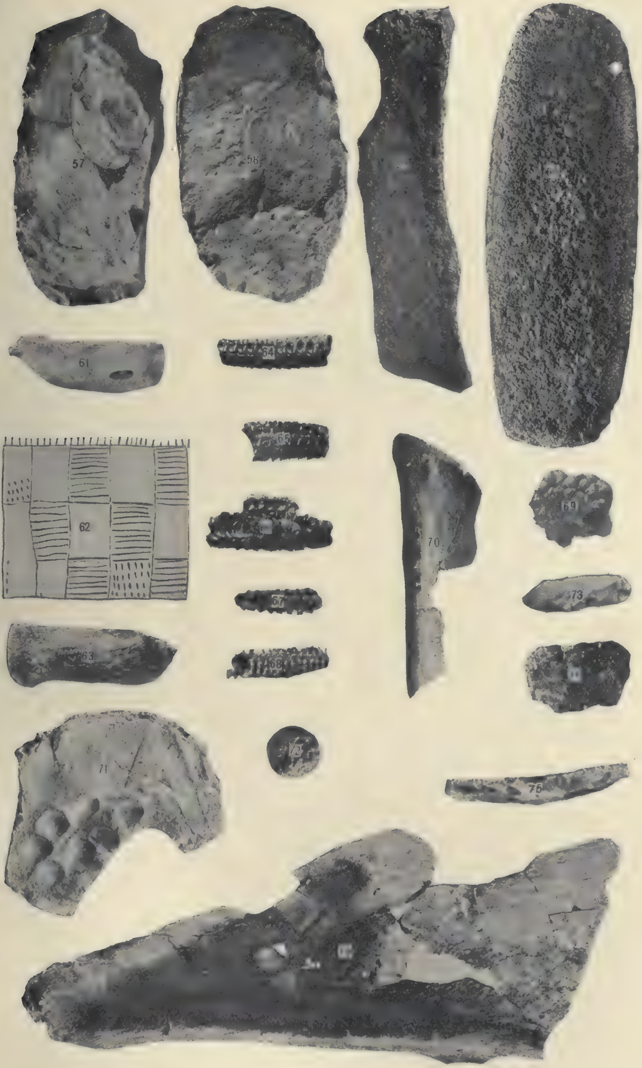
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PLATE IX.

Fig. 77.—Small metate or grinder, of sandstone.

Fig. 78.—Grinder made of clay mortar and coarse sand, and baked as hard as rock itself.

Fig. 79.—Hammer worked from a glacial boulder; well made and much worn.

Fig. 80.—Grinder, of very fine granite.

Fig. 81.—Grinder, of material same as figure 78.

Fig. 82.—Grinder, made from glacial boulder.

Figs. 83, 85.—Grinders, of fine sandstone.

Fig. 84.—Knife blade of chert.

PLATE IX.

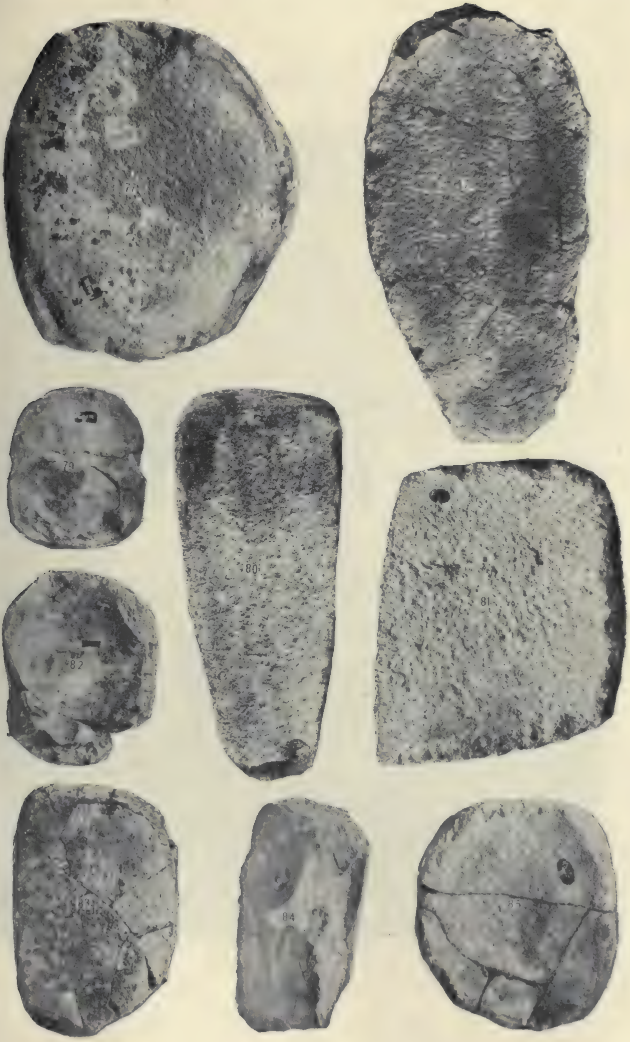
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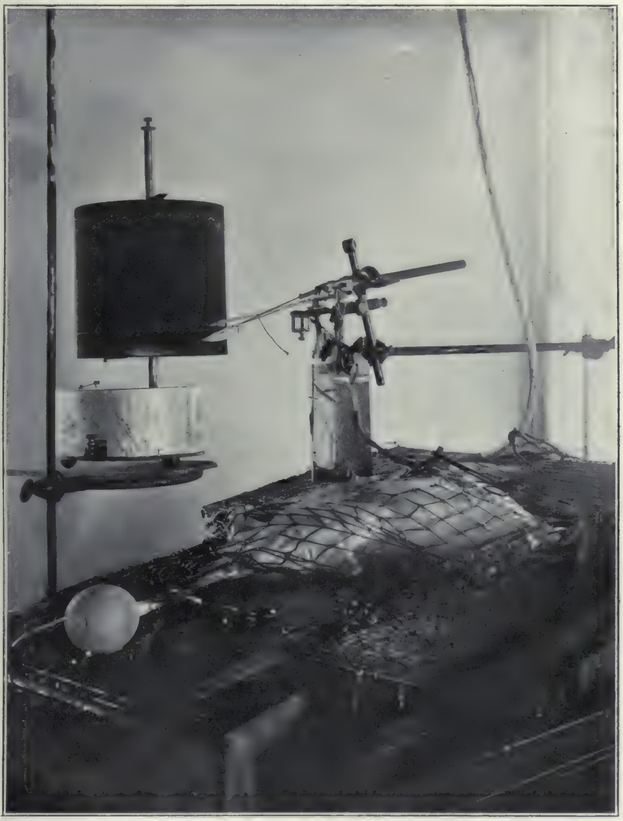
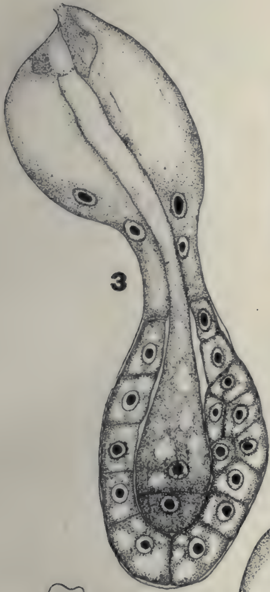
PLATE X.





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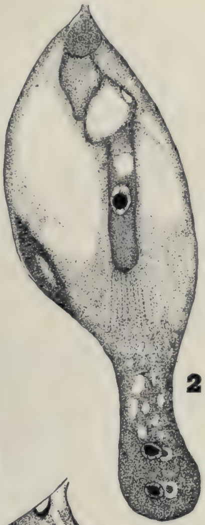

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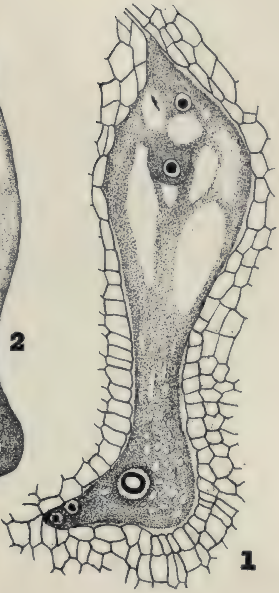

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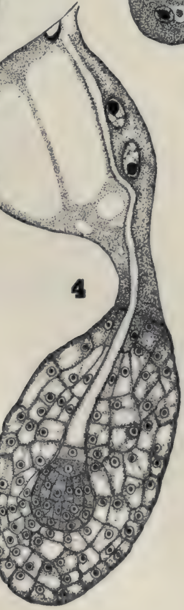

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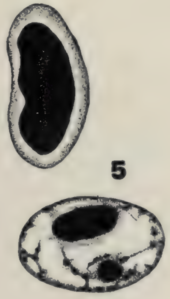

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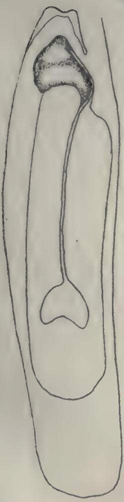

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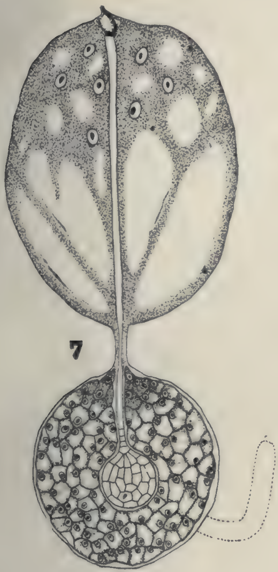

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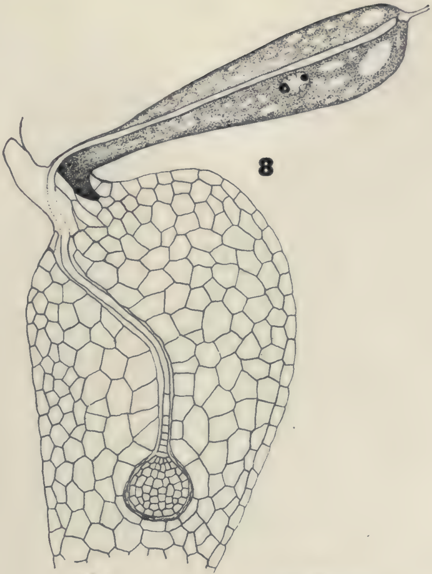

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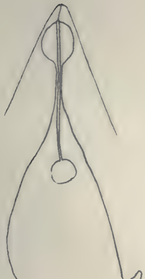

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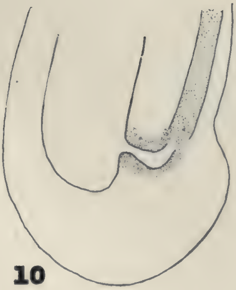

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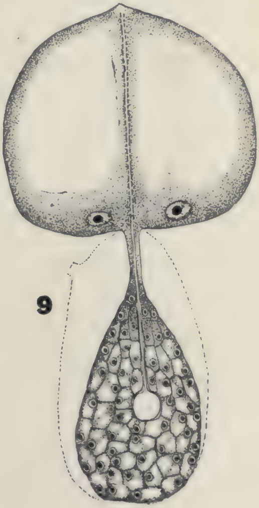

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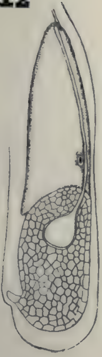

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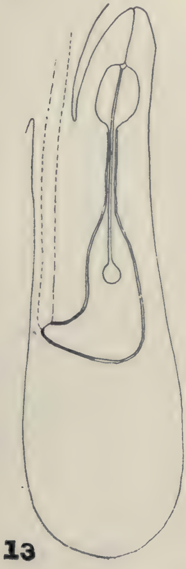

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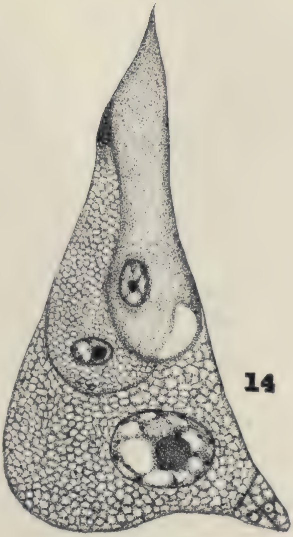

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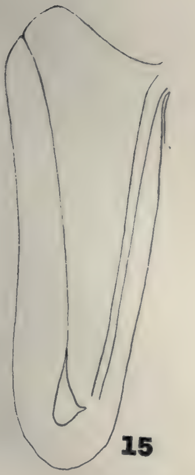

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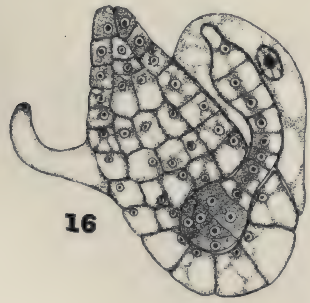

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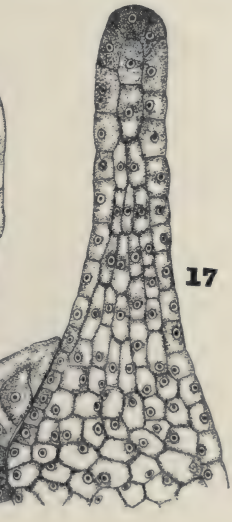

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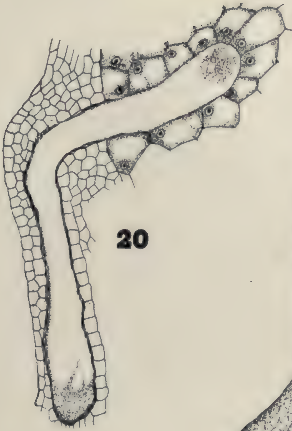

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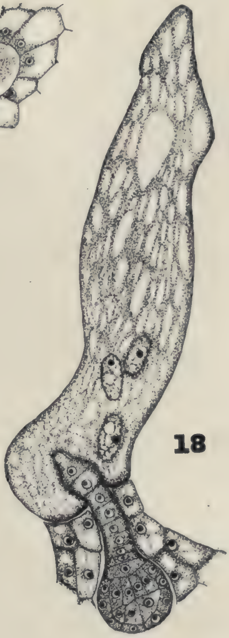

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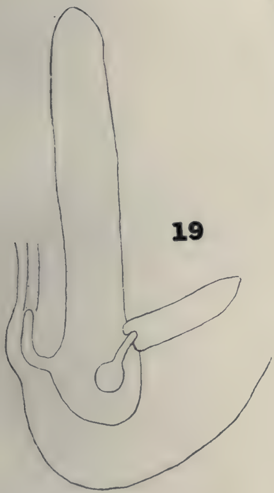

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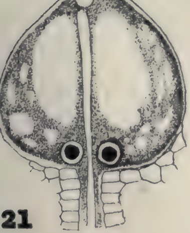

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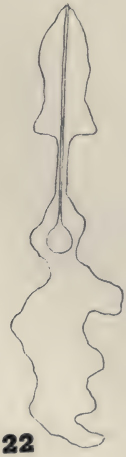

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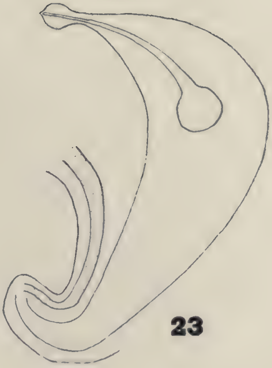

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PLATE XV.

FIG. 1. Two resting cells, showing chromatin granules, and nucleoli with the surrounding clear space.

FIG. 2. Cell beginning mitosis. Close spireme. Nucleoli without the clear space.

FIG. 3. A granular spireme. The nuclear membrane has disappeared but the cytoplasm can still be distinguished from the nuclear sap.

FIG. 4. The chromatin granules are here arranged in rows. This cell has its nuclear membrane yet and the nucleoli have not disappeared.

FIG. 5. Polar view; spireme segmented to form the chromosomes, has a longitudinal split, and is uniformly granular. Nuclear wall just disappeared. Chromosomes looped to form U and J shapes.

FIG. 6. A little later than figure 5. The longitudinal split is very clearly seen.

FIG. 7. Late metaphase. Cytoplasm granular in places, may have been slight plasmolysis in this cell. The spindle fibers are stained very lightly here.

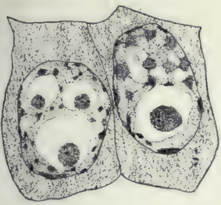
FIG. 8. Metaphase. Spindle shows marked polarity; chromosomes somewhat indefinite.

FIG. 9. Metaphase. Cytoplasm at the ends becoming vacuolated and at the center slightly denser. An especially long chromosome (*m*) is to be noted.

FIG. 10. The cytoplasm of this cell was crushed; however, the chromosomes, which were undivided yet, show the longitudinal split clearly.

FIG. 11. Anaphase. Cytoplasm very granular in places (homogeneous portion not shown). The spindle is well stained in this cell, and the chromosomes have their characteristic bent shape.

FIG. 12. Anaphase. Spindle not clear in this figure. The amount of cytoplasm is small compared to the amount of chromatin here,



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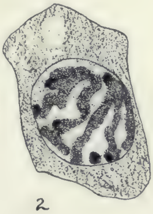

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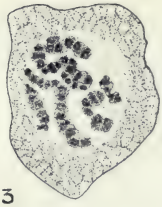

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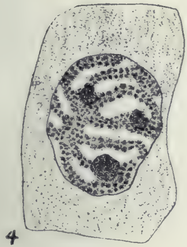

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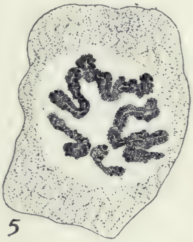

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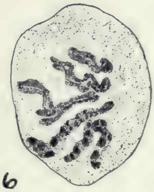

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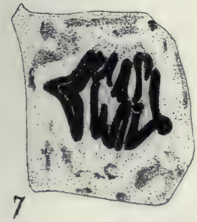

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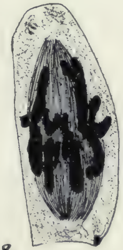

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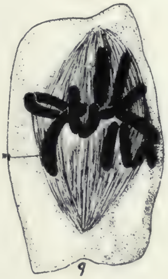

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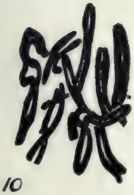

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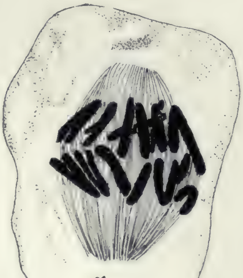

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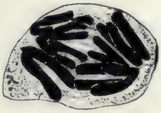

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PLATE XVI.

FIG. 13. Anaphase. Massing of the cytoplasm at the center of the cell.

FIG. 14. Anaphase. The long chromosomes (*m*) are to be seen in this figure.

FIG. 15. Anaphase. Shows relation of chromosomes to spindle during this period.

FIG. 16. Anaphase. Spindle fibers do not show here; reticular cytoplasm (drawn from a slide loaned by Mr. Alban Stewart).

FIG. 17. Anaphase. Polar view; 14 chromosomes.

FIG. 18. Same as 17.

FIG. 19. Telophase. Shows the loosening up of the chromosomes. Cell plate beginning to form.

FIG. 20. Chromatin has diffused throughout the nucleus ahead of the cell-plate formation. A nuclear membrane has also been formed.

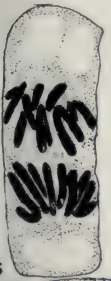
FIG. 21. Chromatin a dense mass, very indefinite at the ends of the cell, not shown; cytoplasm much contracted from the cell wall and concentrated about the spindle.

FIG. 22. A very peculiar spindle; cytoplasm much condensed; a second dense spindle formed about the center of the cell where the cell-plate is appearing. Chromatin not shown.

FIG. 23. Concentrated cytoplasm at the spindle center; a very broad spindle and the cell plate extends entirely across it. Cytoplasm vacuolated; the daughter nuclei, not shown in this figure, are nearly reconstructed.

FIG. 24. Cell plate nearly formed; nuclei reconstructed; cytoplasm concentrated at the center. (From slide belonging to Mr. Stewart.)

PLATE XVI.



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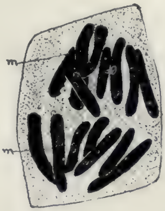

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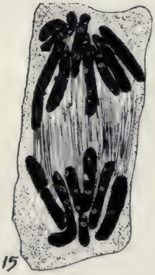

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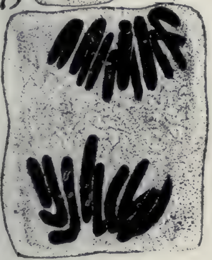

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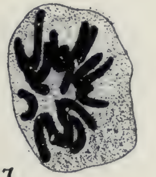

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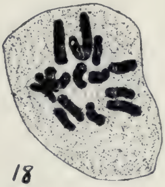

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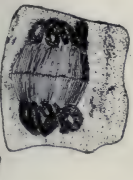

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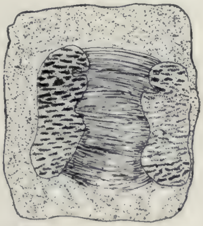

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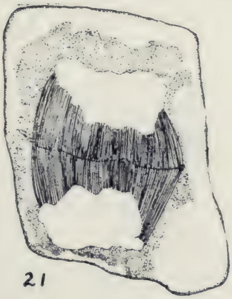

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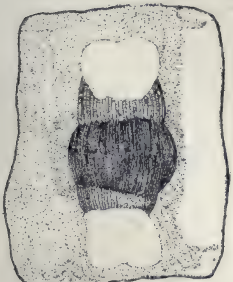

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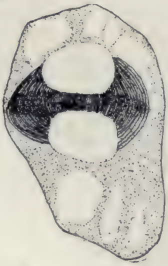

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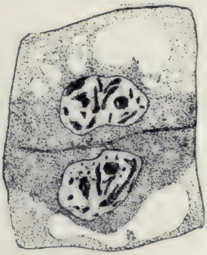

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PLATE XVII.

Koeberlinia spinosa.

FIG. 1.—Branch of *Koeberlinia spinosa.* × about ½.

FIG. 2.—Aspect of vegetation on mesa near Tucson in the neighborhood from which the specimen was taken.
Photographs by L. M. Peace.

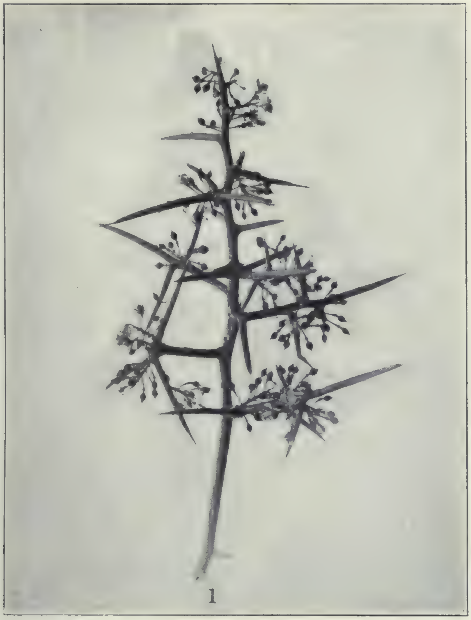

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PLATE XVIII.

Koeberlinia spinosa.

FIG. 1. Cross section of stem. *P*, pith; *M*, medullary ray; *W*, wood; *Tr*, tracheal tubes of year '07 (?); *Ph*, phloëm; *Sa*, spongy parenchyma air space; *Pa*, palisade air space; *Ea*, epidermal air space; *B*, bast; *Scl*, sclerenchymatous tissue. Semi-diagrammatic. × 25.

FIG. 2. (*a*) Section from an older stem, showing traces of annual rings, '07, '05. (*b*) Portion of same stem, opposite side, showing '06 trace. Semi-diagrammatic. × 25.

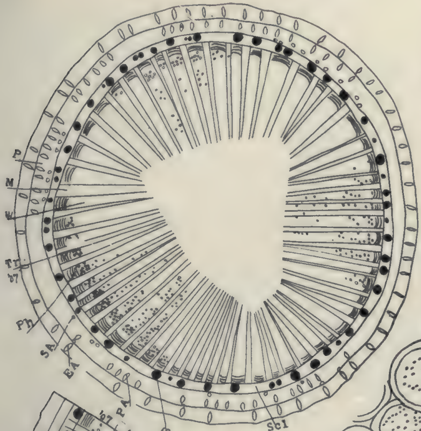
FIG. 3. Cross section of flower branch, showing region of *wa*, water storage cells. × 283.

FIG. 4. (*a*) Pith from flower branch, showing air spaces, *A*. Cross, × 283. (*b*) Single cell from flower-branch pith, showing pits, *P*; air spaces, *A*. Cross, × 400.

FIG. 5. Pith of old stem, showing pitted conditions and starch bodies. Cross, × 283.

FIG. 6. Crystals in old pith cells; longitudinal section. × 283.

FIG. 7. Diagrammatic representation of regions of older stem. *E*, epidermis; *P*, palisade; *Sp*, sponge; *B*, bast; *S*, stone cells; *Ph*, phloëm; *W*, wood. Enlarged.


P
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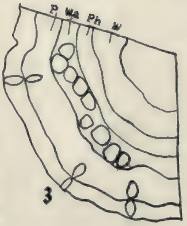
1



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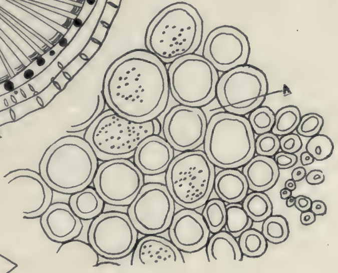

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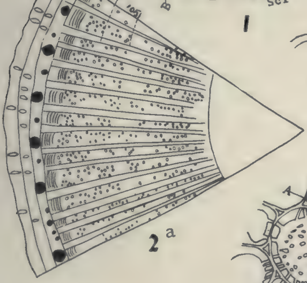

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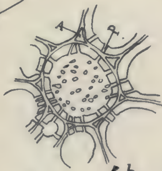

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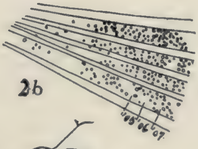

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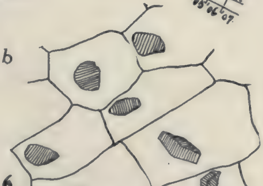

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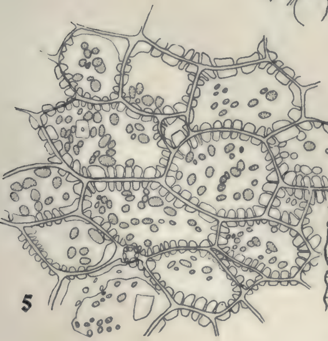

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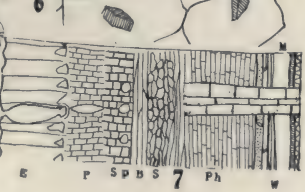

M
E
P
Sp
b
S
Ph
W

7

PLATE XIX.

Koeberlinia spinosa.

FIG. 1. Medullary rays, showing longitudinal extension, longi-tangential section. Semi-diagrammatic. × 55.

FIG. 2. Portion of (1) in detail, showing thick walls, some pits, and numerous aerating places. Tangential. × 283.

FIG. 3. Single medullary ray cell from (2), showing food bodies *F, B;* pits, *P;* aerating spaces, *A*. Longi-tangential. × 636.

FIG. 4. Medullary ray cells, showing one elongated and narrow cell *e. c.*, and some more, box-like, for storage, *St*. Longi-radial, × 283.

FIG. 5. Single storage cell from (4), showing food bodies. Longi-radial, × 636.

FIG. 6. Portion of medullary ray extension in phloëm region, showing thin, unpitted walls and cells filled with nitrogenous material. Longi-radial, × 283.

FIG. 7. Portion of older wood, showing tracheids, *Tr;* fiber tracheids, *Ft*, and wood fibers, *wf*. Cross, × 283.

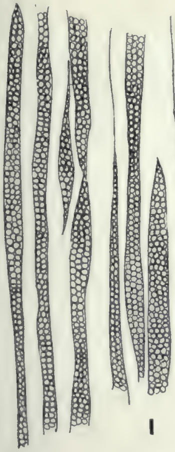
FIG. 8. Detail of (7), showing pitted condition of wood. × 636.

FIG. 9. Water vessels bordering pith. *Tr*, tracheal tubes; *Td*, tracheid; *P*, pith. × 636.

FIG. 10. Spiral tracheids, near pith. Semi-tang., × 283.

FIG. 11. Portion of wood, showing scattered tracheids, *Tr*. Cross, × 283.

PLATE XIX.



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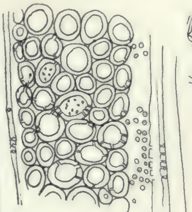

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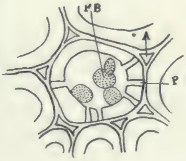

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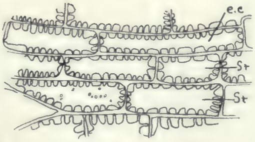

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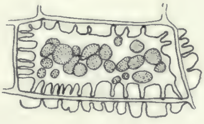

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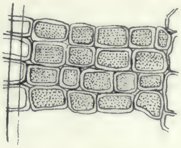

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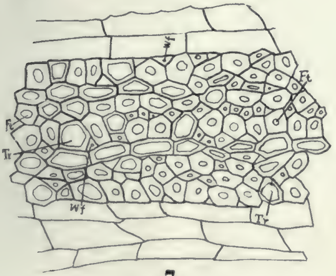
Ft
Ft
Tr
Wf
Tr

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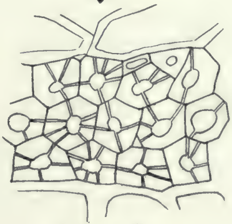

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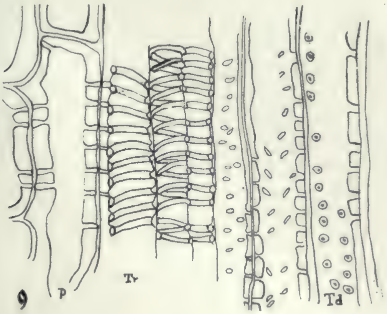

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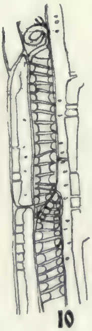

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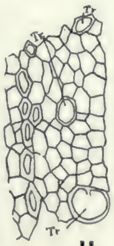

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PLATE XX.

Koeberlinia spinosa.

FIG. 1. Tracheal tube bordering elongated pith cell, on margin of older part of bundle. *P*, pith cell; *Tr*, tracheal tube. Longi-radial, × 636.

FIG. 2. Elongated pith cells densely filled with finely granular food material. Pits in walls omitted. *P*, pith; *W*, wood. Longi-section, × 283.

FIGS. 3, 4, 5, 6. Different views of tracheal tubes, all showing the circular opening at the end. 6 (*a*) Third partition in tube 6, showing section of ring bordering aperture. These have become so completely welded as to give the appearance of a continuous tube, as in 6. Longi-section, × 400. Fig. 3 is the cavity outlined.

FIGS. 7, 8, 9. Sketches showing joining of ends of tracheids. Longi-radial, × 400.

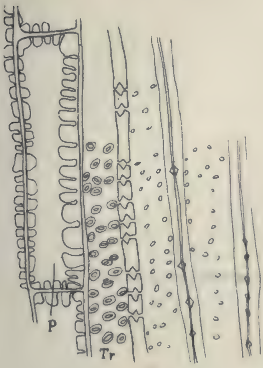
FIGS. 10, 11, 12. Various odd or malformed tracheids. Longi-radial, × 283.

FIG. 13. Regular rectangular tracheids. Longi-radial, × 283.

FIG. 14. Single tracheid. Longi-radial, × 283.

FIG. 15. Fiber-tracheid with small but numerous pits. × 283.

FIG. 16. Wood fiber. Longi-section, × 283.



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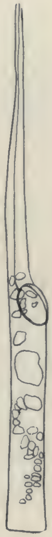

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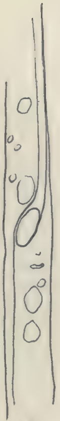

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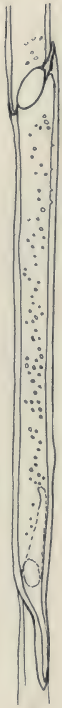

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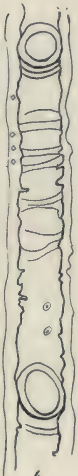

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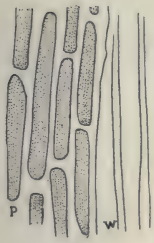

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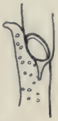

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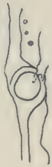

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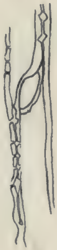

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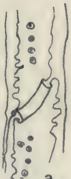

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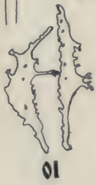

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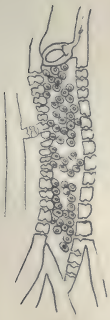

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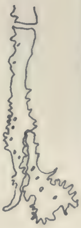

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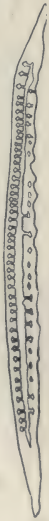

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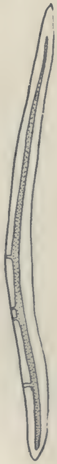

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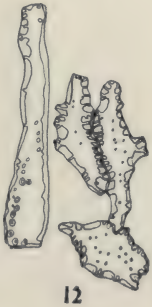

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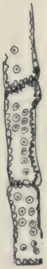

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PLATE XXI.

Koeberlinia spinosa.

FIG. 1. Five rows of phloëm parenchyma cells *p. p.*, as seen in cross section; *m*, medullary-ray cells. × 283.

FIG. 2. Sketch of portion of phloëm, *Ph*, region bordering stone cells, *S*, showing various sizes of cells. Longi-section, × 283.

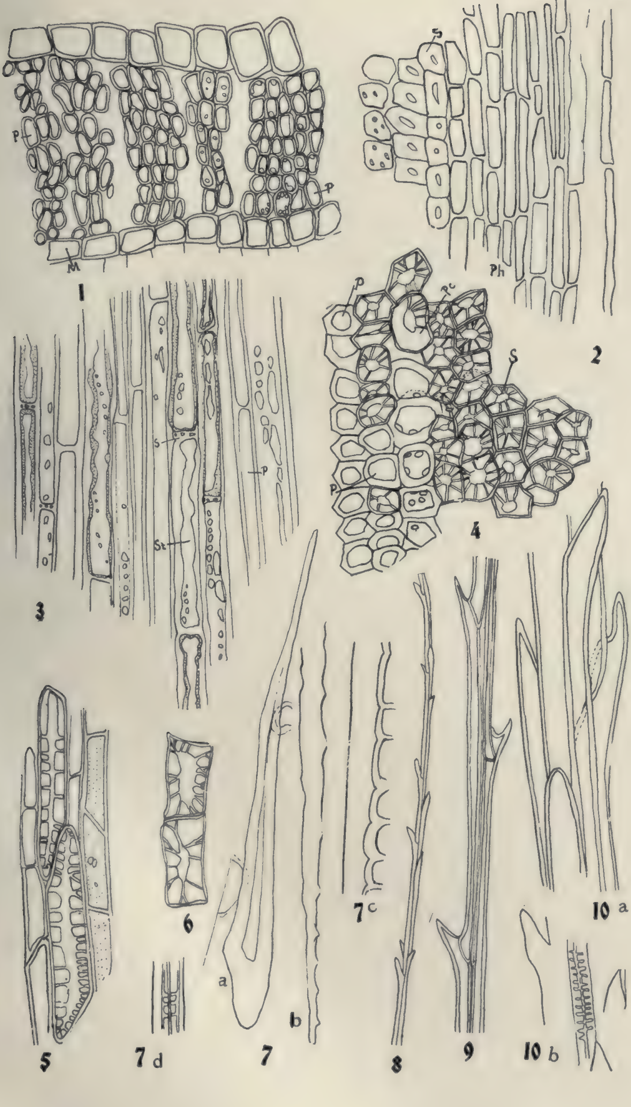
FIG. 3. Portion of (2) in detail, sieve tubes, *St.*, and sieve plates, *S*, and parenchyma cells alongside, *p*. Longi-section, × 400.

FIG. 4. Stone cells bordering spongy parenchyma, showing some cells unlignified, and some but partly lignified, parenchyma cells; *s*, stone cells; *pc.*, partly lignified; *P*, unlignified. Cross section, × 283.

FIGS. 5, 6. Different sizes and shapes of stone cells. Longi-section, × 283.

FIG. 7. (*a*) Tapering bast fiber. (*b*) Portion of long bast fiber, showing tapering part and projections of wall to support neighboring cells. (*c*) Projections with adjoining cellulose walls in detail. (*d*) Pits in long fiber. All × 283.

FIGS. 8, 9, 10*a*, × 55, 283, 636, respectively. Short bast fibers as they occur securely fastened together. 10*b*, sketch showing pits in short bast fiber, × 636.


S
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P
M
1
Ph
2
p
Pc
S
P
4
S
St
P
3
5
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7d
a
b
7
7c
8
9
10a
10b

PLATE XXII.

Koeberlinia spinosa.

Fig. 1. Portion of palisade *P*, and spongy parenchyma, *Sp*, tissue, from stone cells to epidermis. Numerous intercellular spaces *I. S.*, are found. Cross section, × 283.

Fig. 2. End view of palisade cells, showing number and size of chlorophyll bodies. Tangential section, × 283.

Fig. 3. Epidermis of young stem, showing large cellular space, *cs*, and thin walls; this also shows frequency of deeply sunken stomata, *ss*. Cross, × 283.

Fig. 4. Portions of older epidermis, showing reduction of cell space by intense cutinization; cell space, *cs;* cutinized portion, *cp*. Cross, × 283.

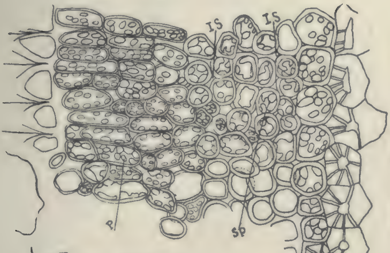
Fig. 5. Tangential view of older epidermal cells, showing thickening of walls. × 283.

Fig. 6. Single stoma from young stem, showing large guard cells, *Gc*. Also, small stomatal chamber proper, above and below, *sc*. Cross, × 283.

Fig. 7. Outer stomatal chamber invaded by phycomycete, *Ph*. Cross, × 283.

Fig. 8. Stomatal apparatus. *OA*, *outermost aperture; E*, epidermal cell space; *osc*, outer stomatal air chamber; *isc*, inner stomatal air chamber; *Pr*, projection of thickening, making stomatal spaces proper, *ssp; P*, palisade cells; *AS*, air space in sponge. Cross, × 283.

Fig. 9. Outline of regions of aerating spaces, showing frequency of spaces. *E*, epidermal region; *p*, palisade region; *s*, sponge region. Enlarged.



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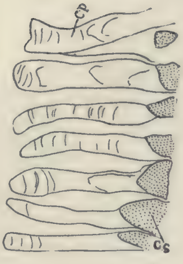

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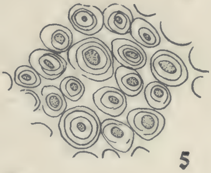

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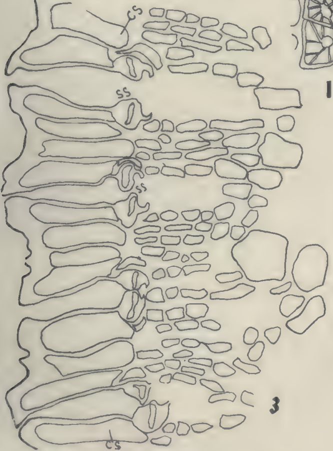

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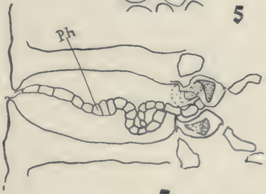

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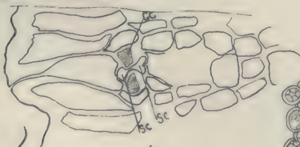

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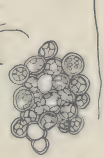

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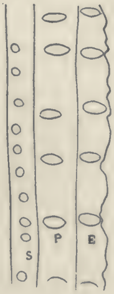

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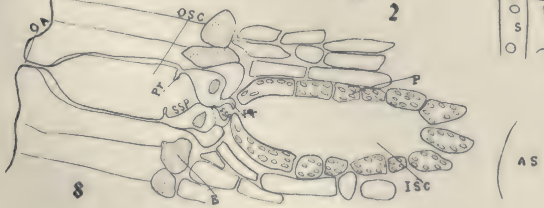

OA
OSC
PY
P
SSP
AS
B
ISC

8

PLATE XXIII.

Koeberlinia spinosa.

FIG. 1. *S,* stone cells filling up lower stomatal chamber; *Ph,* remains of Phycomycete in outer aperture; *d,* portion of "dome." Cross section, × 283.

FIG. 2. Surface view of outer stomatal aperture and epidermal cells. *SA,* stomatal aperture; *EC,* epidermal cells. Tangential section, × 283. Compare with fig. 3, plate XXII.

FIG. 3. View toward outer stomatal aperture from within, showing tips of cells making the "dome." Tangential section, × 283.

FIG. 4. Section across mid-chamber. Tangential, × 283.

FIG. 5. View looking toward stoma, showing shelf, *s,* made by projecting walls. Tangential, × 283.

FIG. 6. Stoma proper, showing guard cells. Tangential, × 283. Compare with fig. 6, plate XXII.

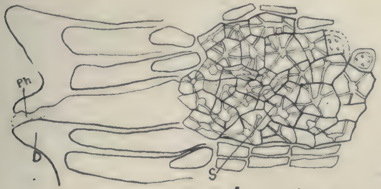
FIG. 7. Stoma proper, invaded by growth of Phycomycete, *Ph.* Tangential section.

FIG. 8. Water-storage cells, *W,* in flower branch, and aerating space, *A.* Cross, × 283.

FIG. 9. Portion of older stem, showing empty cells, *W,* probably for water storage. Cross, × 283.

FIG. 10. Water-storage cells, *W,* and aerating space, *A,* in flower branch. Cross, × 283.

FIG. 11. Aerating space, *A,* in spongy parenchyma. Longi-section, × 283.



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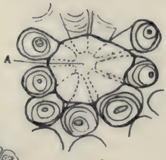

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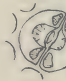

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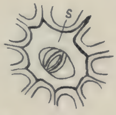

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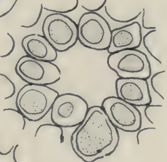

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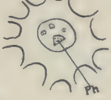

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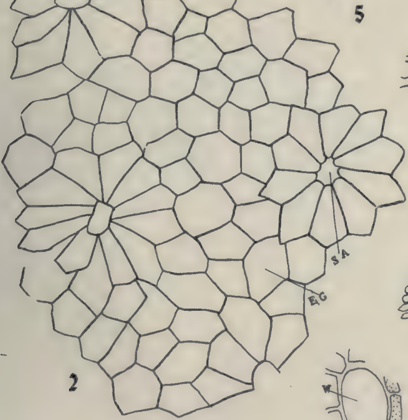

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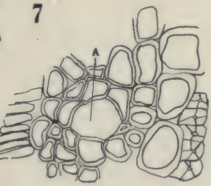

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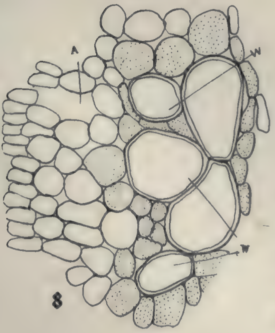

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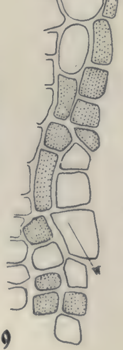

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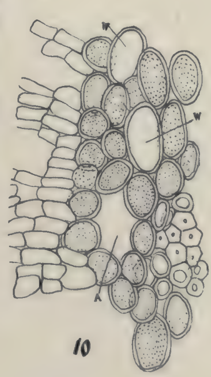


10

PLATE XXIV.

Fig. 1. Resinous-gum cells, *RD*, surrounding vascular bundles in elongated portion of receptacle. Cross, × 283.

Fig. 2. Resinous-gum cells in elongated portion of receptacle, *RD*. Longi-section, × 283.

Fig. 3. Resinous-gum cells, *RD*, surrounding ovule. × 283.

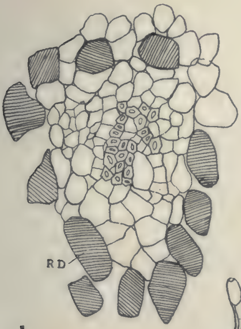
Fig. 4. Section of ovary. *X*, position of structures shown in figs. 1 and 2. Longi-section, × 5.

Fig. 5. Section showing position of mucilage reservoirs and other tissues in ovary. *MR*, mucilage reservoirs; *MC*, mucilage cells; *E*, epidermis; *p*, palisade tissue; *M*, mesophyll; *vb*, vascular bundle. Longi-section, × 55.

Fig. 6. Ovary. Reference letters same as (5). Cross, × 55.

Fig. 7. Portions of (6) more in detail. *OV*, ovule; *S*, stoma; for the other letters, see (5). Cross, × 283.

Fig. 8. Diagrammatic representation of regions in wall of ovary. Reference figures as above. Cross section enlarged.



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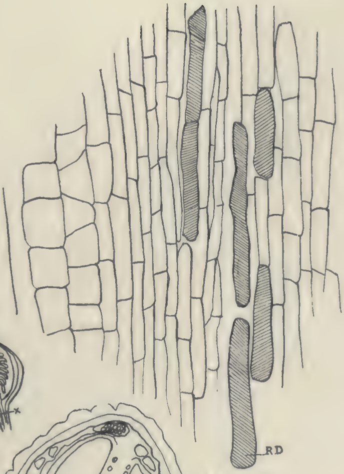

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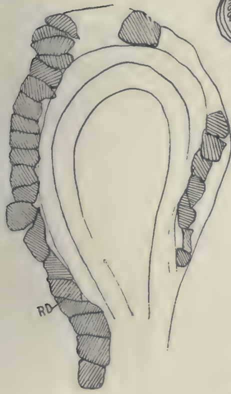

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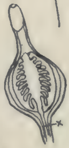

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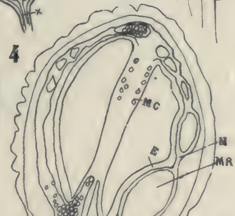
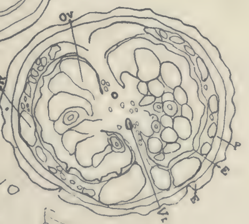

MC
N
E
MR
Vb
E
P

5



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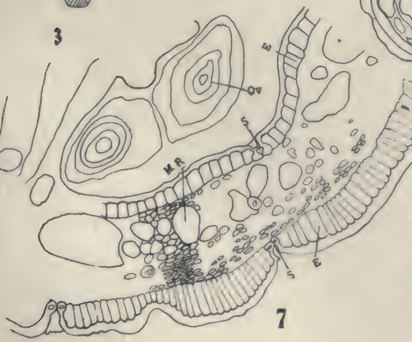

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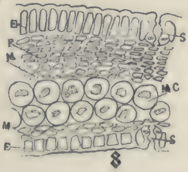


8

PLATE XXV.

FIG. 1. Portion of ovary wall in detail. *OE*, outer epidermis; *M*, mesophyll; *Mr*, mucilage reservoirs; *IE*, inner epidermis; *IS*, inner stoma; *VB*, vascular bundles. Cross, × 283.

FIG. 2. Stoma from inner epidermis of ovary wall. Cross, × 283.

FIG. 3. Outline of portion of ovary wall, showing frequency of inner stomata, *S*. Cross, enlarged.

FIG. 4. Outer stoma, enlarged. Cross, × 283.

FIG. 5. Inflorescence, showing fruit. × 1.

FIG. 6. Single flower stalk. Sepals and petals dropped. Stamen *L* longer than stamen *S*. × 5.

FIG. 7. Single flower. × 5.

FIG. 8. Section of anther, showing number of locules and thin-walled epidermis. Cross, × 283.

FIG. 8*a*. Pollen grain. × 636.

FIG. 9. Sunken stomata on outer epidermis of petals. × 283.

FIG. 10. Portion of petal, showing thin-walled epidermis. Cross, × 283.

PLATE XXV.

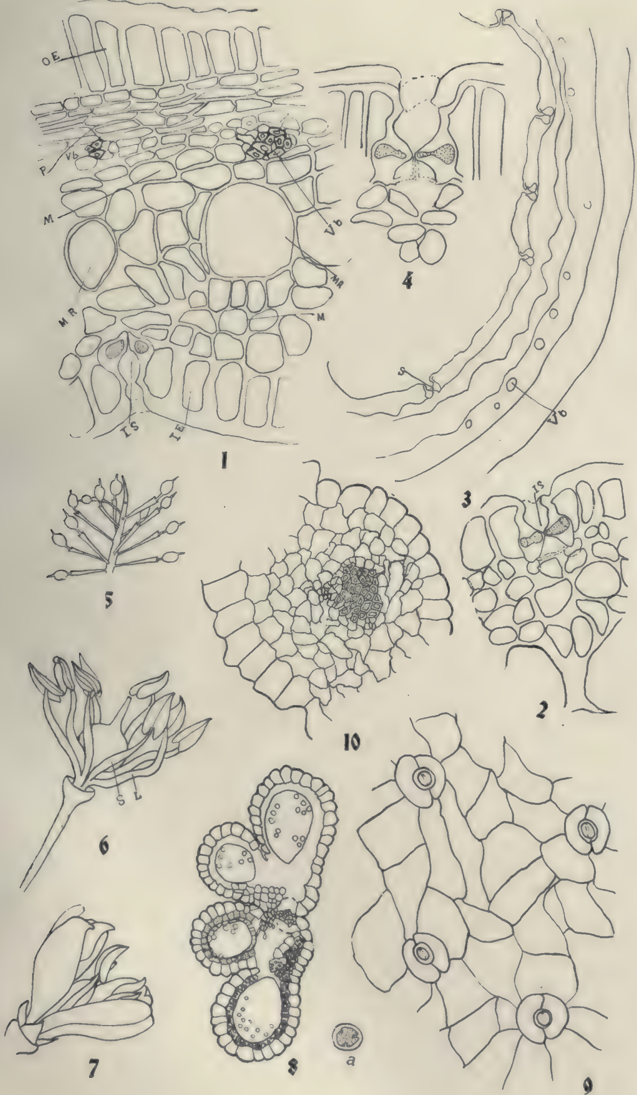

OE
P
Vb
M
Vb
MR
MR
M
IS
IE
1
4
S
Vb
3
IS
2
5
10
S
L
6
7
8
a
9

PLATE XXVI.

Fig. 1.—Cross section through ovipositor, about midway: A. *cmgd,* cement gland duct; *ovid,* oviduct; *uv,* upper valve; *lv,* lower valve; *tg,* tongue and groove; *spg,* subgenital plate. B. Diagram showing position of ovipositor relative to plates.

Fig. 2.—Sport anal (?) vein of adult: *A,* anal vein; *C,* costa; *sv,* sport anal (?) vein.

Fig. 3.—Diagram of tracheation of nymphal wing pad of *P. celtidis-gemma* fore wing: *C,* costa; *Sc,* subcosta; *R,* radius; *M,* media; *Cu,* cubitus; *af,* anal fold; *A,* anal vein.

Fig. 4.—Diagram of tracheation of wing of recently emerged adult of *P. celtidis-mammæ,* fore wing.

Fig. 5.—Longitudinal-vertical section through wax glands: A. *wg,* wax glands; *n,* nucleus; *cu,* cuticula; *sh,* sense organs; *wgd,* wax gland ducts; *fb,* fat body. B. *wgo,* openings of wax glands, dorsal aspect.

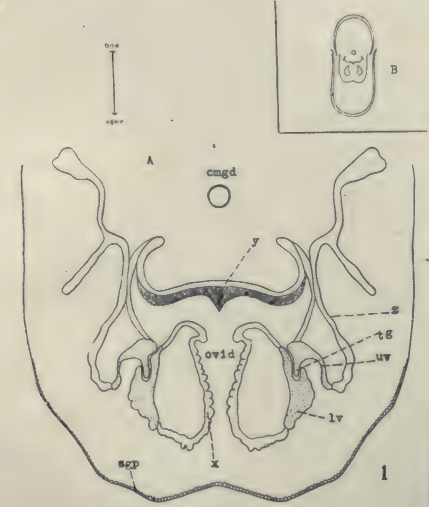
Fig. 6.—Tip of mandible.

Fig. 7.—Tip of maxilla.

Fig. 8.—Base of mandible: *te,* tendon.

Fig. 9.—Base of maxilla.

PLATE XXVI.


dor.
vent.
B
A
cmgd
y
z
tg
uv
ovid
lv
x
sgp

1

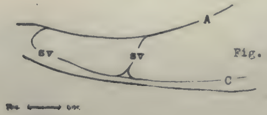
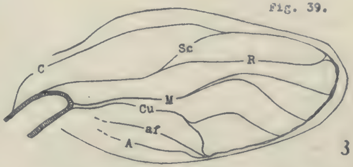


Fig. 41.

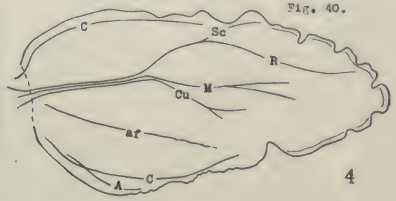
2

Fig. 39.

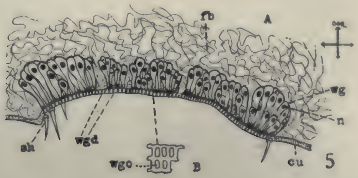

C
Sc
R
M
Cu
af
A

3

Fig. 40.

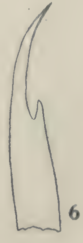

C
Sc
R
M
Cu
af
A
C

4


fb
A
dor.
wg
n
sk
wgd
wgo
B
cu

5

Fig. 25. x5000.



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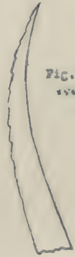
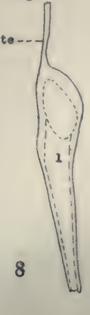


Fig. 26. x5000

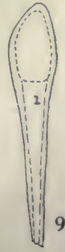
7

Fig. 27. x6



8

Fig. 28. x65



9

PLATE XXVII.

FIG. 1.—Lateral aspect of prothorax and mesothorax, diagrammatic: *pn*, pronotum; *es 1*, proepisternum; *es 1*, proepimeron; *pstr*, prosternum; *pcox*, procoxa; *sp*, spiracle; *dor*, dorsulum; *mm*, mesonotum; *scu*, scutellum; *artep*, articulatory epidemes; *bp*, base of primary; *em 2*, mesoepimeron; *es 2*, mesoepisternum; *mstr*, mesosternum; *end*, portion of endoskeleton.

FIG. 2.—Caudal aspect of mesothorax, diagrammatic: *ter*, tergum; *str*, mesosternum; *phr*, phragma; *apoph*, apophyse; *c*, canal; *apod*, apodeme; *es 2*, mesoepisternum; *em 2*, mesoepimeron; *end*, portion of endoskeleton corresponding to *end* in fig. 1, plate XXVII.

FIG. 3.—Sclerites forming tergum of thorax: A. *pn*, pronotum of prothorax; *dor*, dorsulum of mesothorax; *mm*, mesonotum of mesothorax; *scu*, scutellum of mesothorax; *mett*, metathorax. B. *median*, longitudinal section through tergum.

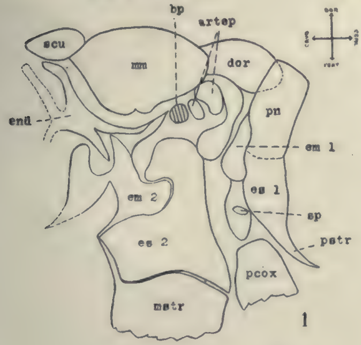
FIG. 4.—Chitinized process holding labium to thorax (cephalic aspect): A. *a*, lateral arm of process; *b*, yoke-like piece connecting lateral arms, caudad and dorsad of labium. B, tip of a lateral arm.

FIG. 5.—Ventral aspect of metathorax, diagrammatic: *str*, metasternum; *cox*, coxa; *em 3*, metaepimeron; *mer*, meracanthus; *troc*, trochanter; *mf*, ventral edge of metafurca.

FIG. 6.—Venation of adult of *P. celtidis-mammæ*, fore wing: *c*, costa; *Sc + R*, subcostal plus radius; *s*, stigma; *Sc*, subcosta; *R*, radius; *M 1 2*, media; *M 3 4*, media; *Cu 1*, cubitus; *Cu 2*, cubitus; *af*, anal fold or "claval suture"; *cl*, clavus; *A*, anal vein; *Pc*, petiolus cubite.

FIG. 7.—Venation of adult of *P. celtidis-mammæ*, hind wing.

FIG. 8.—Ventral aspect of subgenital plate of female: *b*, base of plate; *a*, apex of plate; *sh*, sensory hairs.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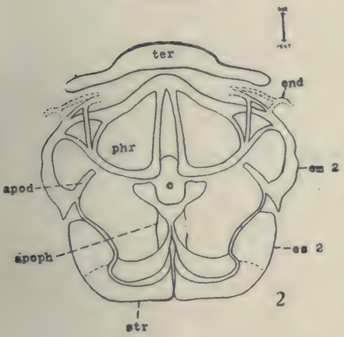
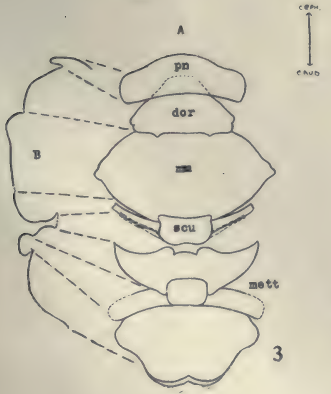
artep
scu
mn
dor
pn
end
em 1
em 2
es 1
sp
es 2
pstr
pcox
mstr

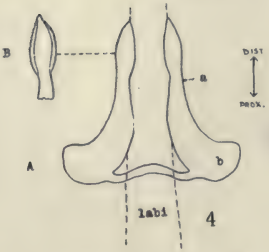
1


ter
end
phr
em 2
apod
c
apoph
es 2
str

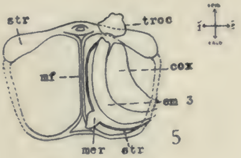
2


A
CEPH.
CAUD
pn
dor
B
mn
scu
mett

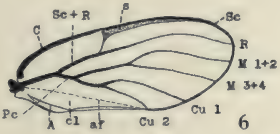
3


B
A
DIST
PROX.
a
b
labi

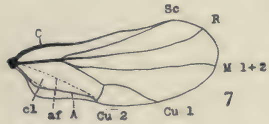
4


str
troc
mf
cox
em 3
mer
str

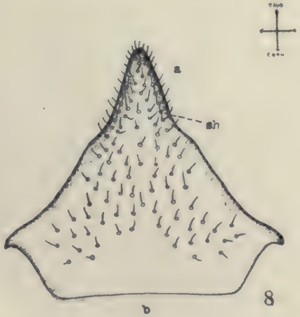
5


Sc + R
s
Sc
C
R
M 1+2
M 3+4
Pc
A
cl
af
Cu 2
Cu 1

6


Sc
R
C
M 1+2
cl
af
A
Cu 2
Cu 1

7


CAUD
CEPH
a
sh
b

8

PLATE XXVIII.

FIG. 1.—Caudal aspect of head: *ep*, epicranium; *e*, compound eye; *fo*, front ocellus; *g*, gena; *fc*, frontal cone; *a*, antennal segments; *y*, projection from gena; *x*, portion of membrane forming fold around labium between procoxæ.

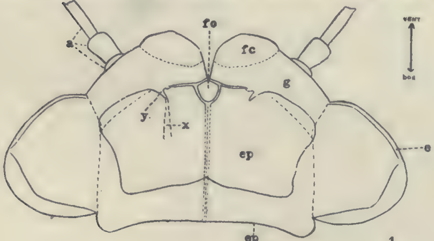
FIG. 2.—Longitudinal section of front ocellus: *cu*, cuticula; *hyp*, hypodermis; *l*, lens; *ip*, iris pigment; *v*, vitreous body; *r*, retinal cells; *n*, nerve.

FIG. 3.—Antenna.

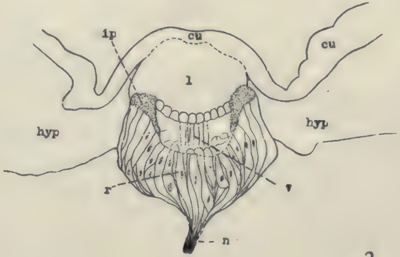
FIG. 4.—Cephalic aspect of head: *ep*, epicranium; *e*, compound eye; *o*, ocellus; *fo*, front ocellus; *g*, gena; *fc*, frontal cone; *a*, antennal segments; *as*, antennal socket.

FIG. 5.—Ventral aspect of head: *ep*, epicranium; *e*, compound eye; *fo*, front ocellus; *g*, gena; *fc*, frontal cone; *as*, antennal socket; *p*, projection from edge of antennal socket; *y*, projection from gena; *f*, frons; *lp*, ligamentary process of frons.

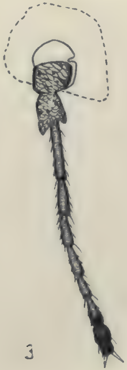
FIG. 6.—Articulation between third and fourth antennal segments: *a*, third segment; *b*, fourth segment; *cor*, corrugations; *sh*, sensory hairs.


fo
fc
a
g
y
x
ep
e
ep
VENT
DOR

1


lp
cu
cu
l
hyp
hyp
r
v
n

2



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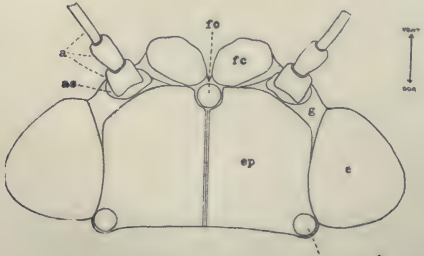
fo
fc
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as
g
ep
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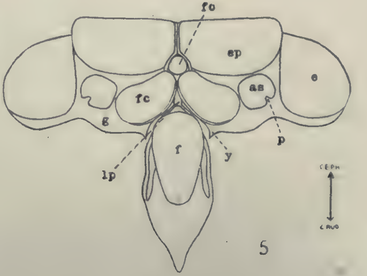
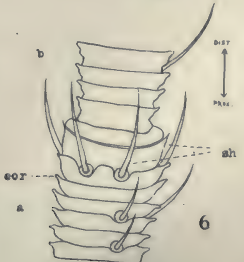
VENT
DOR

4


fo
ep
e
as
fc
g
p
f
y
lp
CEPH
CAUD

5


b
DIST
PROX.
sh
cor
a

6

PLATE XXIX.

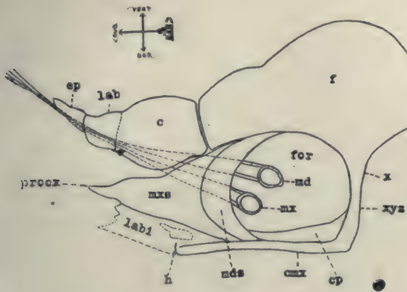
FIG. 1.—Lateral aspect of mouth parts, labium excepted: *f*, frons; *c*, clypeus; *lab*, labrum; *ep*, epipharynx; *md*, mandible; *mx*, maxilla; *mds*, mandibular sclerite; *mxs*, maxillary sclerite; *cmx*, chitinized plate for muscular attachment; *cp*, hypopharyngeal lamella; *procx*, maxillary process; *labi*, labium (base); *h*, hypopharynx; *for*, foramen.

FIG. 2.—Lateral aspect of mouth parts (diagrammatic): *f*, frons; *ep*, epipharynx; *s*, setæ; *labi 1*, *labi 2*, *labi 3*, three segments of labium; *mestr*, mesosternum; *p*, process of thorax for holding labium; *m*, membrane forming fold between procoxæ for labium.

FIG. 3.—Ventral aspect of mouth parts, labium excepted: *f*, frons, *c*, clypeus; *lab*, labrum; *ep*, epipharynx; *md*, mandible; *ms*, maxillæ; *cmx*, chitinized plate for muscular attachment; *cp*, hypopharyngeal lamella; *mds*, mandibular sclerite; *mxs*, maxillary sclerite; *procx*, maxillary process.

FIG. 4.—Ventral aspect of labium: *f*, frons; *c*, clypeus; *lab*, labrum; *ep*, epipharynx; *labi 1*, *labi 2*, *labi 3*, three segments of labium; *b*, point where bend occurs.

FIG. 5.—Dorsal aspect of mouth parts, labium excepted: *f*, frons; *lab*, labrum; *ep*, epipharynx; *md*, mandible; *mx*, maxillæ; *cmx*, chitinized plate for muscular attachment; *cp*, hypopharyngeal lamella; *procx*, maxillary process; *h*, hypopharynx; *t*, tentorium; *z*, proximal edge of frons; *p*, pharynx.


ep
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c
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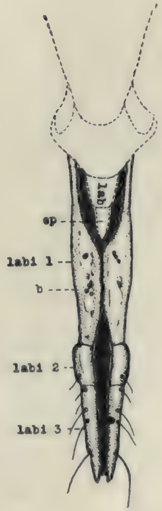
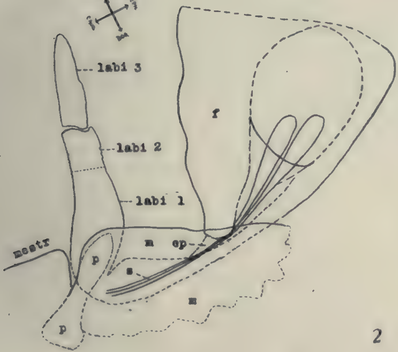
md
mx
x
xyz
procx
mxs
labi
h
mds
cmx
cp

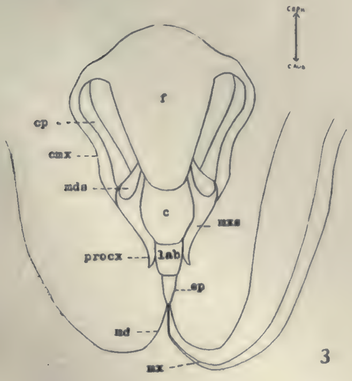
1


lab
ep
labi 1
b
labi 2
labi 3

4


labi 3
labi 2
labi 1
f
mestr
p
m
ep
s
m
p

2


CEPH
CAUD
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md
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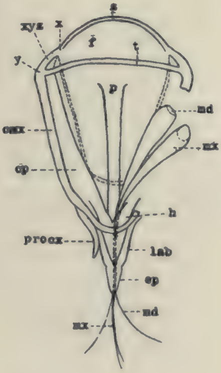
3


s
xyz
x
f
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y
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md
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cmx
cp
h
procx
lab
ep
md
mx

PLATE XXX.

FIGS. 1, 2 and 3.—Lateral, dorsal and ventral aspects of ovipositor, diagrammatic: *uv*, upper valves; *lv*, lower valves; *vs*, upper and lower valves (fig. 2); *buv*, base or support for *uv; blv*, base or support for *lv*; *sh*, sheath; *v*, valve closing oviduct; *procv*, process of rod for closing *v*; *sc*, laterally diverging pairs of sclerites cephalad of sheath (fig. 1); *sc 1*, proximal pair of sclerites; *sc 2*, distal pair of sclerites; *stp*, sting-palpi; *mr*, median rod; *lr*, lateral tendenous rod flattening out into lightly chitinized lateral plates, *lpt*.

FIG. 4.—Diagram showing position of ovipositor: *spp*, supra-anal plate; *a*, opening of anus; *sgp*, subgenital plate; *v*, valves of ovipositor; *sh*, sheath of ovipositor tip.

FIG. 5.—Lateral aspect of metafurca.

FIG. 6.—Caudal aspect of supra-anal plate: *spp*, supra-anal plate; *sppfl*, inner edges or flaps of supra-anal plate; *x*, distal portion of plate; *a*, anal opening; *lp*, lateral plate; *co*, base of copulatory organ; *l*, loop below copulatory organ.

FIG. 7.—Lateral aspect of supra-anal plate and copulatory organ: *spp*, supra-anal plate; *sppfl*, inner edges or flaps of supra-anal plate; *x*, distal portion of plate; *a*, anal opening; *lp*, lateral plate; *co*, copulatory organ; *g*, geniculation; *c*, club; *p*, penis; *l*, loop below copulatory organ; *y*, slit in base of copulatory organ.

FIG. 8.—Cephalic aspect of metathorax, diagrammatic: *str*, metasternum; *mf*, metafurca; *la*, lateral projection of endoskeleton; *mett*, metatergum.

FIG. 9.—Section through fore wing: *wm*, wing membrane; *b*, pigmented disc; *a*, unpigmented disc; *c*, cuticular processes on ventral surface of wing.

Fig. 94.

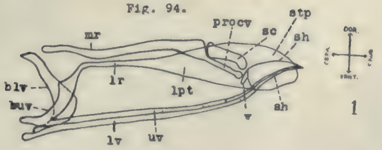
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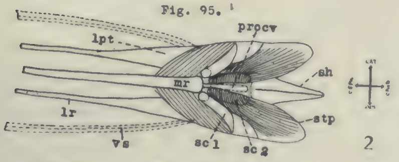
Fig. 95.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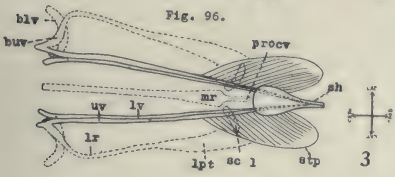
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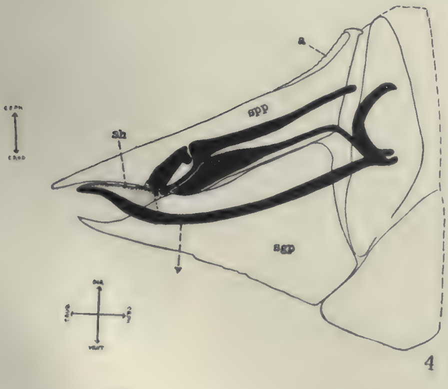
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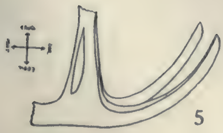

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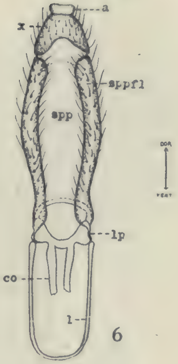
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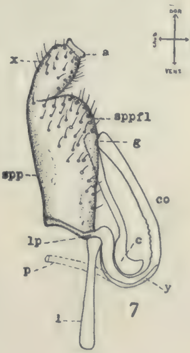
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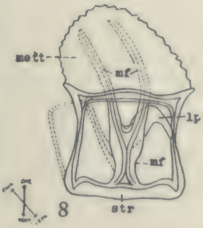
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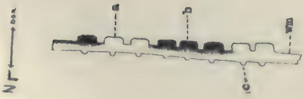

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PLATE XXXI.

Fig. 1.—Cross section through procoxæ and mouth parts: *cox*, coxa; *c*, clypeus; *p* and *pc*, parts of pharyngeal canal; *mds*, mandibular sclerite; *mxs*, maxillary sclerite; *s*, setæ; *cp*, hypopharyngeal lamella; *m*, membrane forming fold between procoxæ to hold labium.

Fig. 2.—Lateral aspect of tip of labium: *t*, lateral tongue-like processes; *sh*, sense organs.

Fig. 3.—Cephalic aspect of tip of labium: *t*, lateral tongue-like processes; *sh*, sense organs; *sl*, slit of labium.

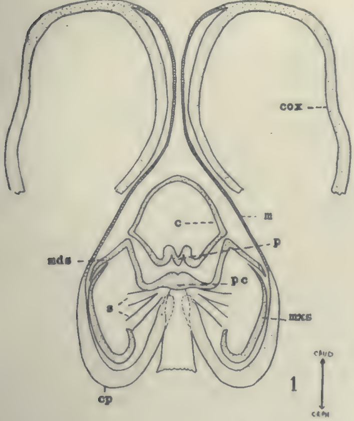
Fig. 4.—Base of supra-anal plate of female showing wax glands: *a*, anal opening; *wgo*, openings of ducts of wax glands; *sh*, sense organs; *x*, chitinized portion of plate; *y*, slightly chitinized, translucent portion of plate.

Fig. 5.—Cross section of *labi 1*: *md*, mandible; *mx*, maxilla; *m*, longitudinal muscles; *sl*, slit of labium; *l*, lumen in mandible.

Fig. 6.—Cross section of ovipositor through base of sheath: *spp*, supra-anal plate; *sgp*, subgenital plate; *ovid*, oviduct; *sh*, sheath; *stp*, sting-palpi.

Fig. 7.—Lateral aspect of metathorax, part of metasternum, epimeron, meracanthus, coxa, etc., removed, diagrammatic: *mett*, metatergum; *mf*, metafurca; *bs*, region of base of secondary; *es 3*, region of metaepisternum; *str*, part of metasternum; *end*, a rod connected to metafurca; *x*, point of articulation of *em 3*.

Fig. 8.—Lateral aspect of metathorax, part of metasternum, episternum and metafurca removed, diagrammatic: *mett*, metatergum; *mf*, metafurca; *str*, part of metasternum; *mer*, meracanthus; *em 3*, metaepimeron; *cox*, coxa; *scl*, an accessory sclerite; *x* and *y*, articulation of *em 3*; *troc*, trochanter; *fem*, femur.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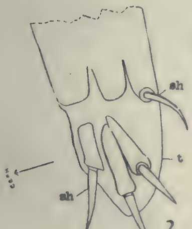

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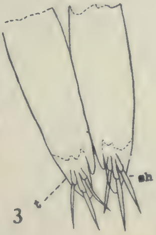

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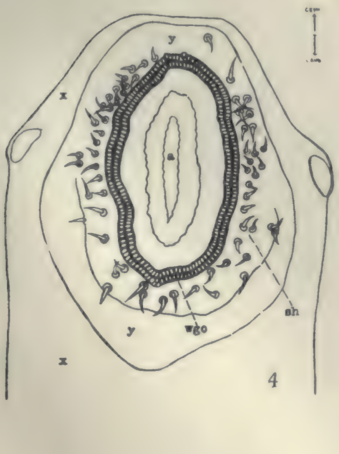
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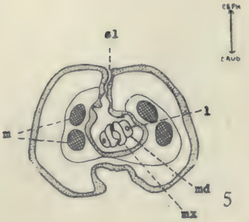
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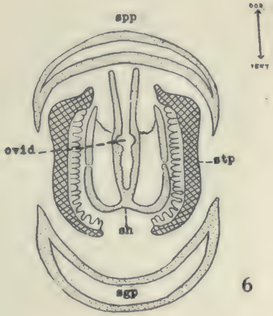
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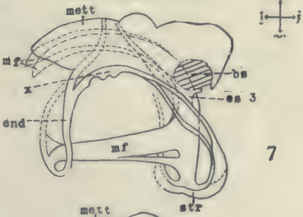
Fig. 37. x71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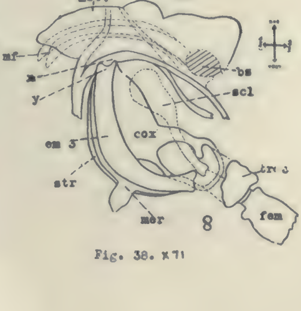
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Fig. 38. x71

PLATE XXXII.

FIG. 1.—Frons and mouth parts, labium excepted, removed from head. (Photo.)

FIGS. 2, 3 and 4.—Wings of male. (Photos.)

FIGS. 5, 6 and 7.—Wings of female. (Photos.)

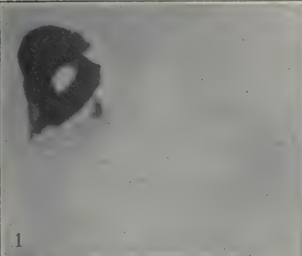
FIG. 8.—Tracheation of nymphal wing pad of *P. celtidis-gemma*, fore wing. (Photo.) *C*, costa; *Sc*, subcosta; *R*, radius; *M*, *M*, media; *Cu*, *Cu*, cubitus.

FIG. 9.—Tracheation of wing of recently emerged adult of *P. celtidis-mammæ*, fore wing. (Photo.) *C*, costa; $Sc + R$, radius plus subcosta; *R*, radius; *M*, media; *Cu*, cubitus.

FIG. 10.—Branching of media and cubitus from radius plus subcosta in fore wing of recently emerged *P. celtidis-mammæ:* $Sc + R$, radius plus subcosta; *M*, media; *Cu*, cubitus.

FIG. 11.—Branching of subcosta and radius in fore wing of recently emerged *P. celtidis-mammæ:* *Sc*, subcosta; *R*, radius; *C*, costa.

PLATE XXXII.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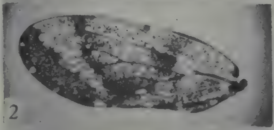
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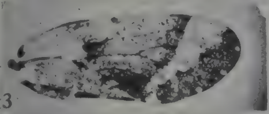
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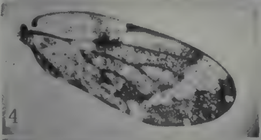
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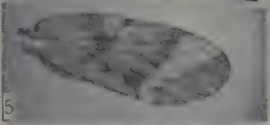
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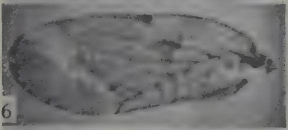
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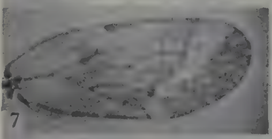
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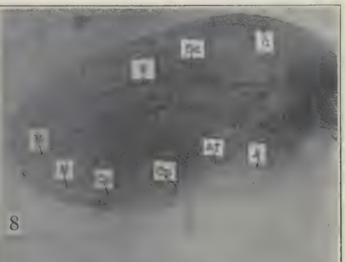
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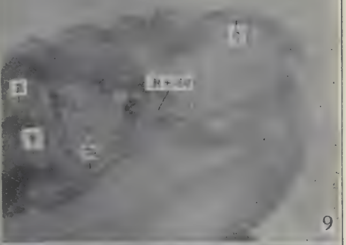
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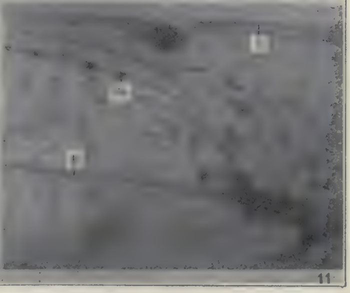
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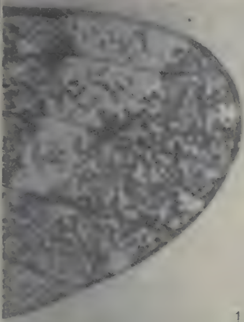
PLATE XXXIII.

Fig. 1.—Apex of wing of male, showing pattern. (Photo.)
Fig. 2.—Hind wing. (Photo.)
Figs. 3 and 6.—Wings of females. (Photos.)
Fig. 4.—Highly magnified portion of pattern. (Photo.)
Fig. 5.—Apex of wing of female, showing pattern. (Photo.)
Fig. 7.—Wing of male. (Photo.)
Fig. 8.—Base of hind wing, showing pattern and hairs on costa. (Photo.)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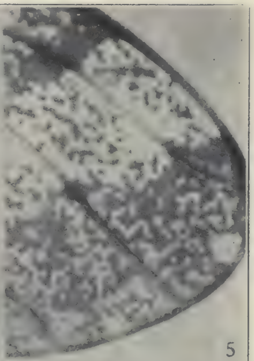
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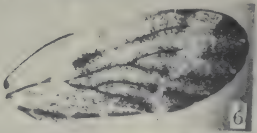
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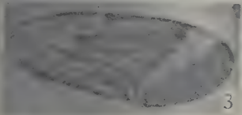
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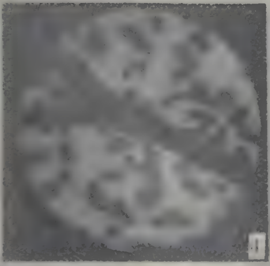
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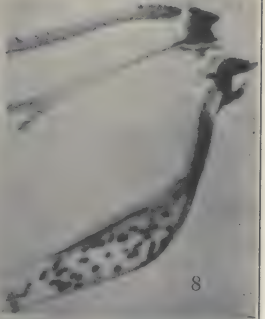
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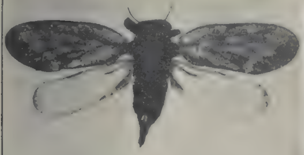
PLATE XXXIV.

Fig. 1.— ——— Dorsal aspect of male. (Photo.)
Fig. 2.— ——— Dorsal aspect of male. (Photo.)
Fig. 3.—Ventral aspect of male. (Photo.)
Fig. 4.—Lateral aspect of female. (Photo.)
Fig. 5.—*Pachypsylla* on bark of hackberry, showing protective markings. (Photo.)
Fig. 6.—Head, antennæ, and mouth parts. (Photo.)
Fig. 7.—Photograph of head and antennæ.
Fig. 8.—Lateral aspect of mouth parts, removed from head. (Photo.)
Fig. 9.—Last four joints of antenna.

PLATE XXXIV.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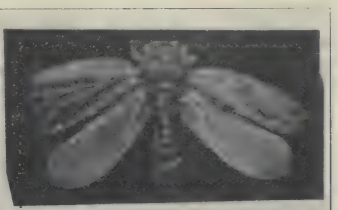
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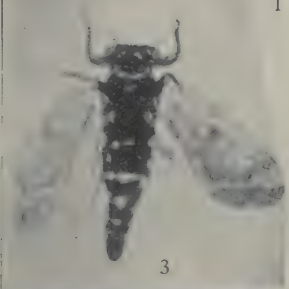
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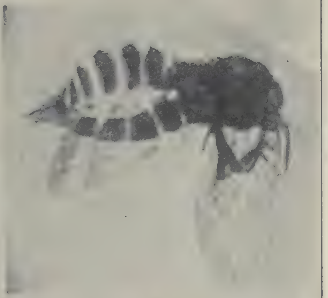
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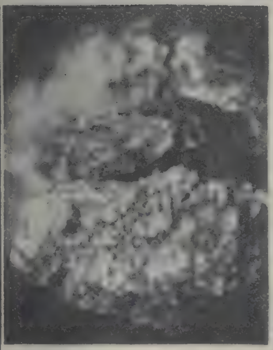
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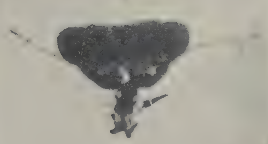
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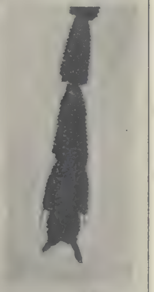
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PLATE XXXV.

FIG. 1.—Metathoracic tarsi. (Photo.)

FIG. 2.—Prothoracic tarsi. (Photo.)

FIG. 3.—Mesothoracic tarsi. (Photo.)

FIG. 4.—Dorsal aspect of supra-anal plate of female. (Photo.)

FIG. 5.—Mesothoracic leg. (Photo.)

FIG. 6.—Prothoracic leg. (Photo.)

FIG. 7.—Lateral aspect of copulatory organ. (Photo.)

FIG. 8.—Metathoracic leg. (Photo.) *scl*, accessory sclerite.

FIG. 9.—Lateral aspect of ovipositor. (Photo.)

FIG. 10.—Lateral aspect of male genitalia. (Photo.) *spp*, supra-anal plate; *sgp*, subgenital plate; *co*, copulatory organ; *f*, forceps.

FIG. 11.— Mesothoracic legs with mesosternum. (Photo.) *apoph*, apophyse.

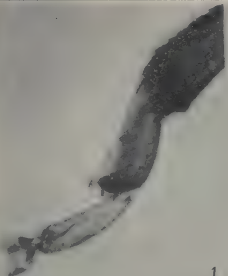
FIG. 12.—Prothoracic legs, pronotum, etc. (Photo.) *pn*, pronotum; *es 1*, proepisternum; *em 1*, proepimeron; *cox*, coxæ.

FIG. 13.—Lateral aspect of female abdomen. (Photo.)

FIG. 14.—Lateral aspect of male abdomen. (Photo.) (Figure inverted.)

FIG. 15.—Cephalic aspect of forceps. (Photo.)

PLATE XXXV.



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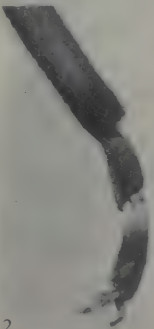

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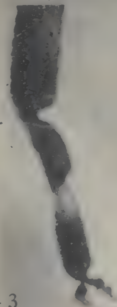

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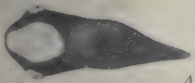

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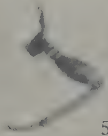

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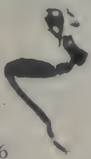

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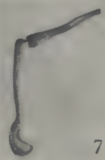

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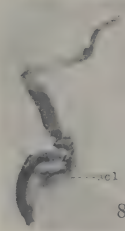

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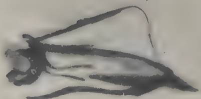

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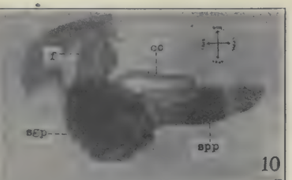

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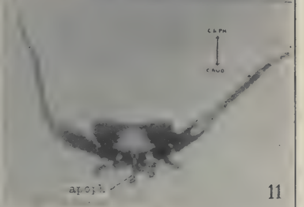
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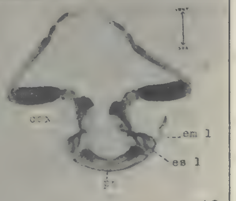

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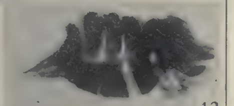

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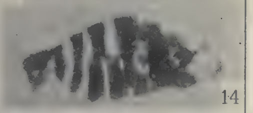

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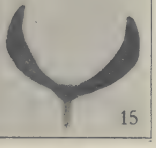

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PLATE XXXVI.

FIG. 1. Tangential section of *Populus alba* with pits in wall between medullary ray and phloëm parenchyma and between two parenchyma cells.

FIG. 2. Side view of obliquely placed end sieve plate from *Populus alba* and with pits between the sieve tubes and the other phloëm cells. Tangential section.

FIG. 3. A pit in a vertical wall between a medullary ray and the phloëm of *Populus alba*.

FIG. 4. Transverse or reticulate strengthening bands on the wall of a sieve tube in a root of *Populus deltoides*. Tangential section.

FIG. 5. Transverse bands on the wall of a sieve tube in the root of *Populus deltoides*, as seen in section.

FIG. 6. Transverse section in *Amorpha fruticosa*, showing the radially elongated medullary-ray cells and others similar to these sweeping around the narrow strip of phloëm and arranged to conduct food from these radially, especially to the cambium.

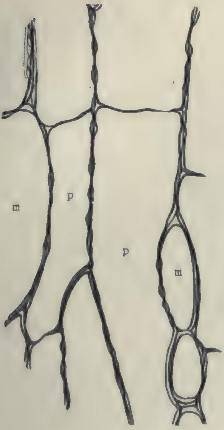
DESCRIPTION OF FIGURES.

Plates XXXVI and XXXVII.

Explanatory notes: Magnification is 600, except in figure 6, where it is 250 approximately.

Lettering: st = sieve tube; m = medullary ray; p = parenchyma; camb = cambium; stch = starch; cr = crystal; pt = pit; n = nucleus.

Symbols: →) and →] = direction toward nearest point of circumference or in the epidermis.



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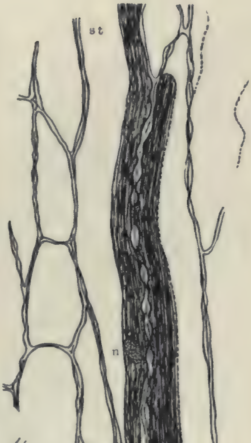

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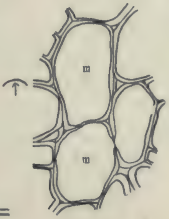

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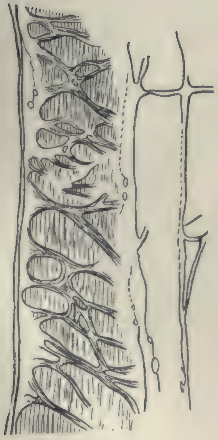

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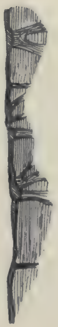

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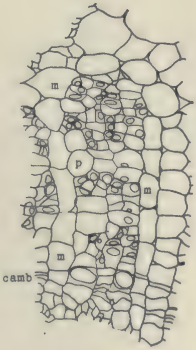

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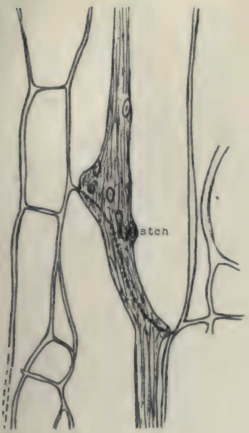
PLATE XXXVII.

FIG. 7. Tangential section of *Populus alba,* showing the "beaded" end plate of a sieve tube and starch granules in the slime body.

FIG. 8. Tangential section in the root of *Populus deltoides,* showing one of the remarkable obliquely placed end plates of a sieve tube in cross section. The strengthening bands here appear as larger beads and the perforation of the wall as spaces between smaller beads. This long plate evidently gives more surface for the distribution of the pits and possibly better communication between the two cells of the sieve tube.

FIGS. 9 and 10 are from tangential sections of the root of *Populus deltoides,* and show the reticulated markings caused by the pitting and banding of the obliquely placed end plates in the sieve tubes. In figure 10 the sieve tube adjoins a medullary-ray cell.

PLATE XXXVII.



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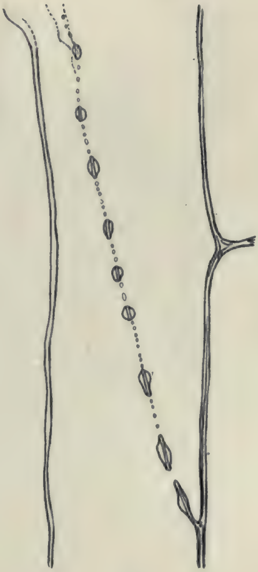

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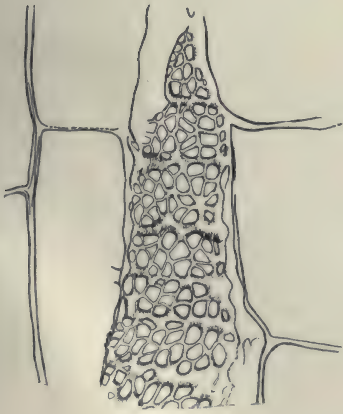

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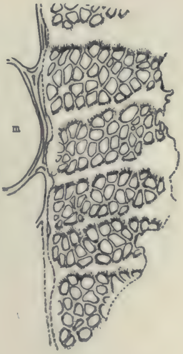

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PLATE XXXVIII.

Townsendia exscapa.

FIG. 1. View from "Castle Rock Bluffs," Gove county, Kansas, showing the habitat of *Townsendia* in the foreground.

PLATE XXXVIII.

PLATE XXXIX.

Townsendia exscapa.

FIG. 2. Photograph of *Townsendia* in flower, showing its habit while young.

FIG. 3. Photograph of *Townsendia* in fruit, top view.

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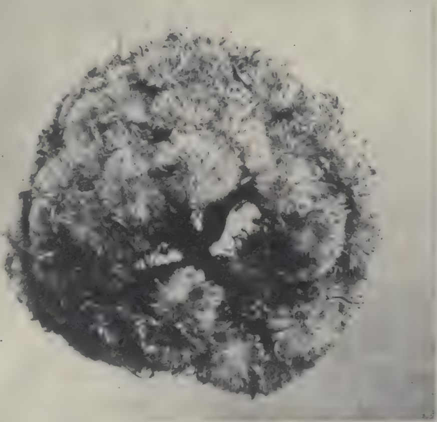

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PLATE XL.

Townsendia exscapa.

FIG. 4. Cutinized epidermis of stem, cross section. *R*, outer tangential wall; *S*, inner tangential wall. × 650.

FIG. 5. Cork cells, cross section. × 650.

FIG. 6. Collenchyma cells, cross section. × 650.

FIG. 7. Collenchyma cells, longitudinal section. × 650.

FIG. 8. Short sclerenchyma cells, cross section. × 650.

FIG. 9. Short sclerenchyma cells, longitudinal section. × 650.

FIG. 10. Cortex cells, cross section. × 650.

FIG. 11. Cortex cells, longitudinal section. × 650.

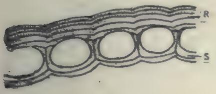
FIG. 12. Pith cells, cross section. × 650.

FIG. 13. Pith cells, longitudinal section. × 650.

FIG. 14. Small portion of xylem, cross section, showing: *a*, tracheids; *b*, wood parenchyma cells. × 650.

FIG. 15. Tracheids, as seen in a longitudinal section, when isolated from the wood parenchyma cells by means of chromic acid. × 650.

PLATE XL.



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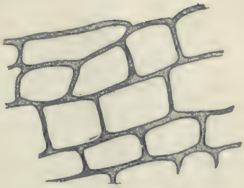

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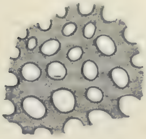

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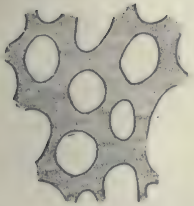

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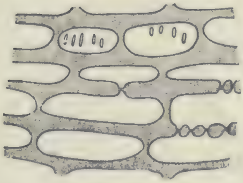

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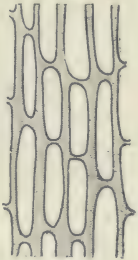

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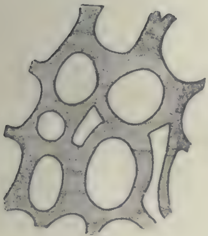

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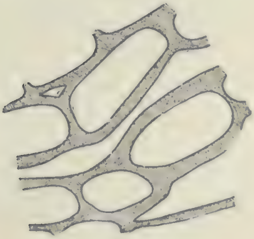

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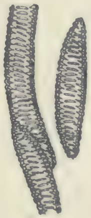

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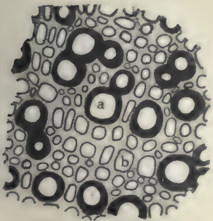

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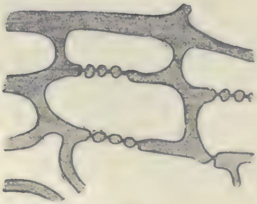

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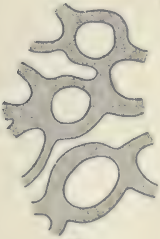

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PLATE XLI.

Townsendia exscapa.

FIG. 16. Medullary-ray cells, cross section. × 650.

FIG. 17. Medullary-ray cells, longitudinal section. × 650.

FIG. 18. Phloëm cells, cross section. × 650.

FIG. 19. Phloëm cells, longitudinal section: *a*, cambiform cell; *b*, undivided mother cell of the sieve tubes. × 650.

FIG. 20. Cross section of root, showing the distribution of tracheids. × 115.

FIG. 21*a*. A bleached leaf, showing its method of venation. × 12½.

FIG. 21*b*. Midrib of leaf, cross section, showing: *a*, phloëm cells; *b*, tracheids; *c*, wood parenchyma cells. × 215.

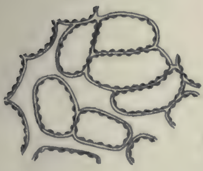
FIG. 22. Portion of a bleached leaf, showing the details of venation. × 115.

FIG. 23. Phloëm cells as seen in a longitudinal section of the midrib of a leaf: *a*, cambiform cell; *b*, undivided mother cell of the sieve tubes. × 650.

FIG. 24. Cutinized epidermis of leaf, cross section: *a*, cuticle; *b*, cutinized portion of wall. × 650.

FIG. 25. Palisade cells, surface view: *c*, intercellular spaces; *d*, palisade cell. × 650.

FIG. 26. Spongy parenchyma cells, surface view. × 650.



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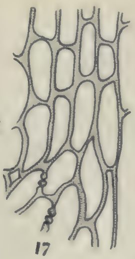

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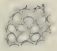

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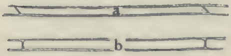

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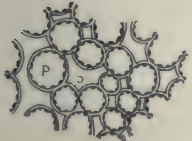

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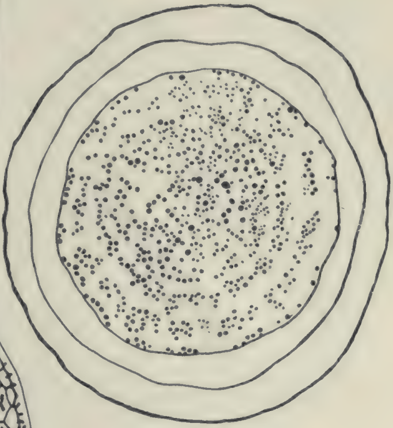

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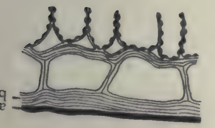

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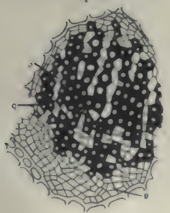

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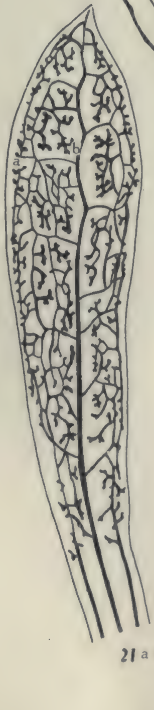

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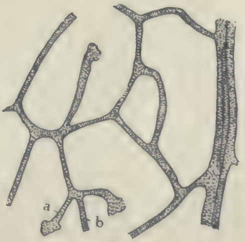

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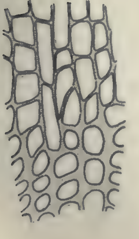

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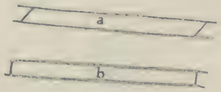

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PLATE XLII.

Townsendia exscapa.

FIG. 27. Diagrammatic drawing showing the distribution of water-storage cells as seen in cross section of a leaf: *a*, veins; *b*, water-storage cells.

FIG. 28. Palisade cells bordering on water-storage cells: *A*, water-storage cells; *B*, palisade cells; *a*, chloroplasts found in water-storage cells. × 650.

FIG. 29. Palisade cells bordering on the veins: *A*, palisade cells; *B*, border parenchyma cells; *C*, tracheids. × 650.

FIG. 30. Palisade cells bordering on water-storage cells and storage tracheids: *A*, water-storage cells; *B*, chloroplasts found in water-storage cells; *C*, water-storage tracheids; *D*, palisade cells. × 650.

FIG. 31. Palisade cells bordering on water-storage cells, which in turn border on veins: *A*, water-storage cell; *B*, chloroplasts; *C*, tracheids; *D*, border parenchyma cells. × 650.

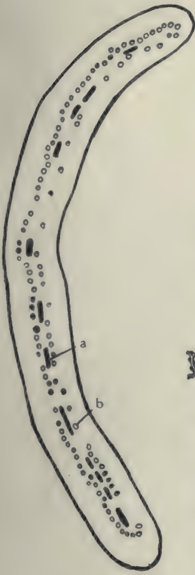
FIG. 32. Palisade cells bordering on spongy parenchyma cells: *A*, palisade cell; *B*, spongy parenchyma cell; *C*, intercellular spaces. × 650.

FIG. 33. Water-storage tracheids as they appear at the ultimate ends of the veins: *A*, veins; *B*, water-storage tracheids. × 650.

FIG. 34. Water-storage tracheids as they appear in other places in the leaf: *A*, ordinary tracheids; *B*, water-storage tracheids. × 650.

FIG. 35. Stomata, surface view. × 650.

FIG. 36. Stoma, as seen in cross section of the leaf. × 650.



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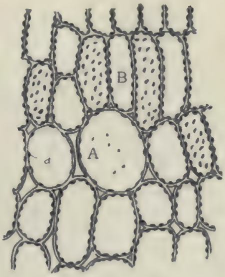

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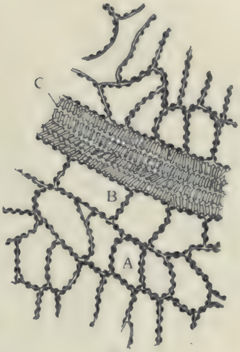

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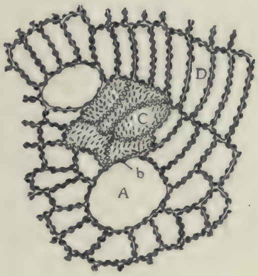

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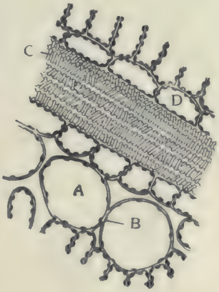

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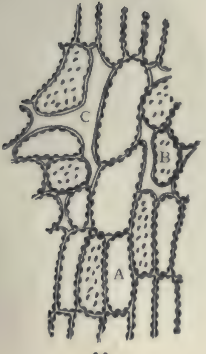

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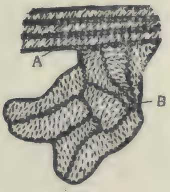

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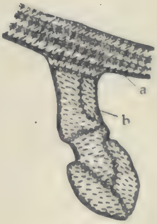

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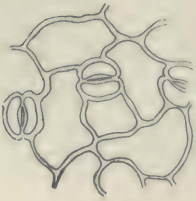

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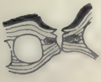

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PLATE XLIII.

Lesquerella spathulata.

FIG. 37. Cutinized epidermis of stem, cross section: *S*, outer tangential wall; *T*, inner tangential wall. × 650.

FIG. 38*a*. Cutinized epidermis of stem, longitudinal section: *S*, outer tangential wall; *T*, inner tangential wall. × 650.

FIG. 38*b*. Cork cells as seen in cross section. × 650.

FIG. 39. Stone cells found in the borke, cross section. × 650.

FIG. 40. Collenchyma cells, cross section. × 650.

FIG. 41. Collenchyma cells, longitudinal section. × 650.

FIG. 42. Stone cells found in sclerenchyma tissue, cross section. × 650.

FIG. 43. Stone cells found in sclerenchyma tissue, longitudinal section. × 650.

FIG. 44. Bast fibers, longitudinal section. × 650.

FIG. 45. Bast fibers, cross section. × 650.

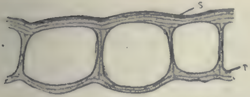
FIG. 46. Small portion of xylem, cross section: *A*, wood fibers; *B*, wood parenchyma cells; *C*, tracheal elements.

FIG. 47. Wood fiber, longitudinal section. × 650.

FIG. 48. Tracheal elements found in the stem at the nodes as seen in longitudinal section: *A*, scalariform type of tracheids; *B*, spiral type of tracheids. × 650.

FIG. 49. Tracheal elements found in the internodes of the stem, as seen in longitudinal section: *A*, spiral tracheal tubes found among the wood fibers; *B*, spiral tracheal tubes found among the wood parenchyma cells; *C*, scalariform tracheal tubes. × 650.

FIG. 50. Diagrammatic drawing of the cross section of the stem: *A*, borke; *B*, collenchyma; *C*, sclerenchyma; *D*, phloëm; *E*, xylem; 1, tracheal tissues; 2, wood fibers; 3, xylem parenchyma; *F*, medullary ray; *a*, leaf trace. × 87½.



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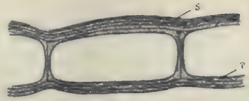

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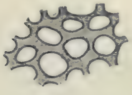

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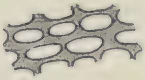

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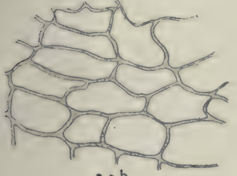

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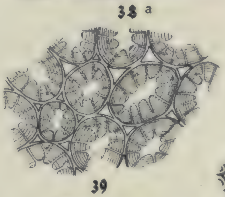

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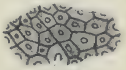

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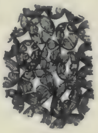

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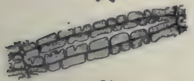

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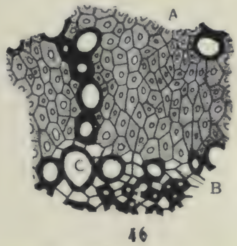

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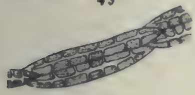

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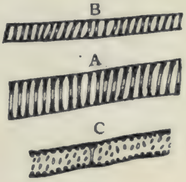

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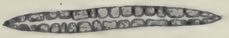

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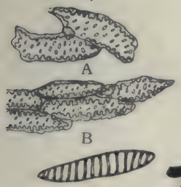

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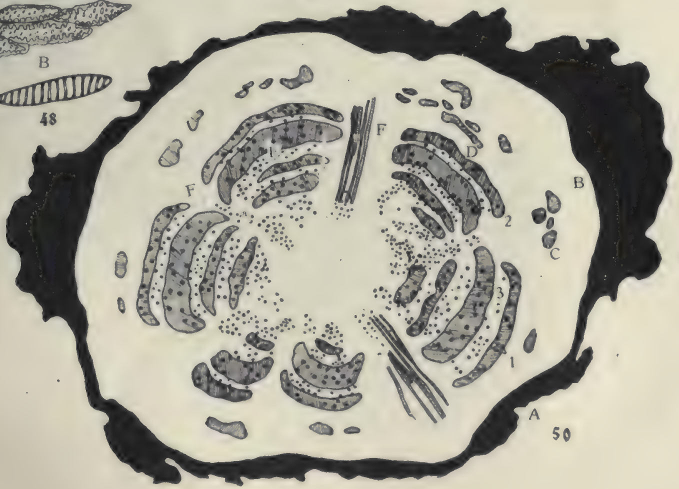

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PLATE XLIV.

Lesquerella spathulata.

FIG. 51*a*. Spiral tracheal tubes found in the leaf trace. × 650.

FIG. 51*b*. Small portion of the medullary ray, as seen in cross section. × 650.

FIG. 51*c*. Phloëm cells, as seen in cross section: *A*, intercellular spaces. × 650.

FIG. 52. Phloëm cells, as seen in longitudinal section: *A*, intercellular spaces. × 650.

FIG. 53. Thin-walled parenchyma cells of the cortex, cross section. × 650.

FIG. 54. Xylem parenchyma cells, as seen in longitudinal section. × 650.

FIG. 55. Wood fibers and tracheal tubes found in the outermost layer of xylem, cross section. × 650.

FIG. 56*a*. Segment of the cross section of the root, showing the constitution of the xylem: *A*, wood fibers; *B*, tracheal elements; *C*, wood parenchyma. × 53.

FIG. 56*b*. Tracheal elements found in the root: *A* and *B*, scalariform tracheal tubes; *C*, spiral tracheal tube. × 650.

FIG. 57. Tracheal tubes and wood parenchyma cells found in the layer of xylem (fig. 56*a*, *F*): *A*, tracheal tubes; *B*, wood parenchyma cells. × 650.

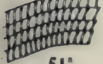
FIG. 58. Wood parenchyma cells, as seen in longitudinal section. × 650.

FIG. 59. Wood fibers and tracheal tubes found in the layer of xylem (fig. 56*a*, *G*). × 650.

FIG. 60. Diagrammatic drawing of the cross section of the root, showing: *A*, cork; *B*, collenchyma; *C*, stone cells; *D*, thin-walled parenchyma; *E*, phloëm; *F*, wood fibers; *G*, wood parenchyma; *H*, tracheal elements; *I*, medullary ray. × 65.

FIG. 61. Cutinized epidermis of leaf: *A*, outer tangential wall; *a*, cutinized portion; *b*, cellulose portion; *B*, inner tangential wall. × 650.

FIG. 62. A bleached leaf, showing the method of venation: *A*, central vein; *B*, lateral branches sent off from the midrib near the center; *C*, two prominent longitudinal veins found on either side of the midrib; *D*, *E*, *F*, terminations of veins; *G*, a large lateral vein sent out from below the center of the midrib, × 27.



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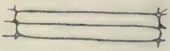

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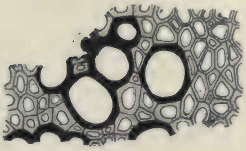

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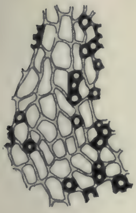

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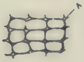

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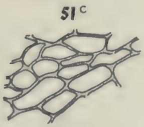

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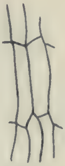

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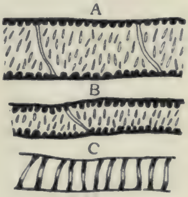

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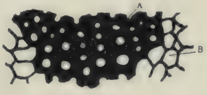

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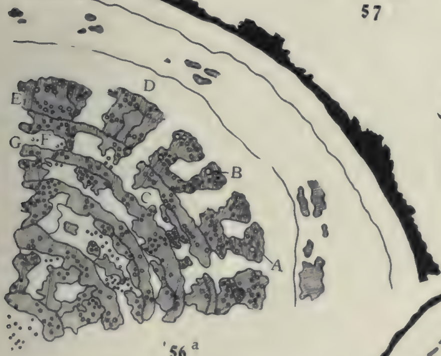

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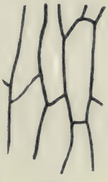

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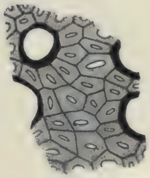

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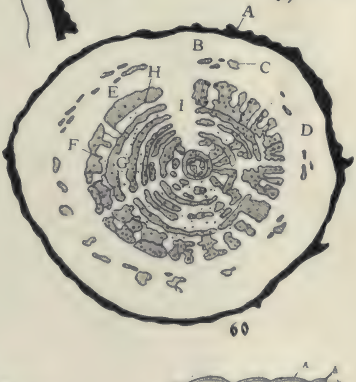

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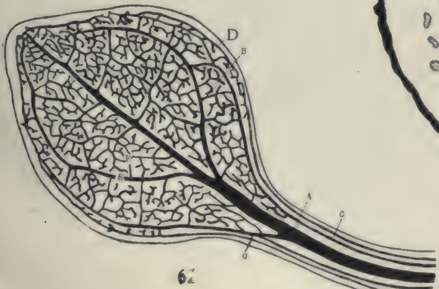

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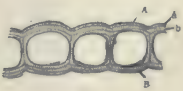

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PLATE XLV.

Lesquerella spathulata.

FIG. 63. Small portion of midrib of leaf, as seen in longitudinal section: *A*, spiral tracheary tracheid; *B*, undivided mother cell of the sieve tubes. × 650.

FIG. 64. Palisade cells, surface view. × 650.

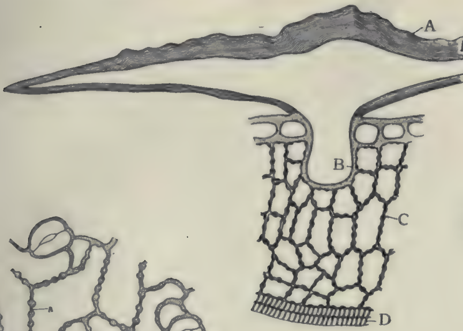
FIG. 65. Trichomes, as seen in surface view of the leaf. × 115.

FIG. 66. Trichome, as seen in leaf, cross section: *A*, cutinized portion of wall of trichome; *B*, cellulose portion of wall of trichome; *C*, mesophyll cells; *D*, tracheids. × 250.

FIG. 67. Stomata, as seen in surface view. × 650.

FIG. 68. Stoma, as seen in cross section. × 650.

FIG. 69. Leaf, as seen in cross section: *A*, upper epidermis; *B*, lower epidermis; *C*, palisade tissue; *D*, vascular bundle. × 250.



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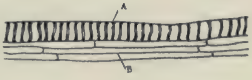

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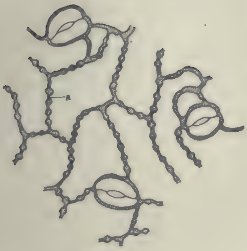

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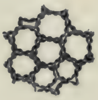

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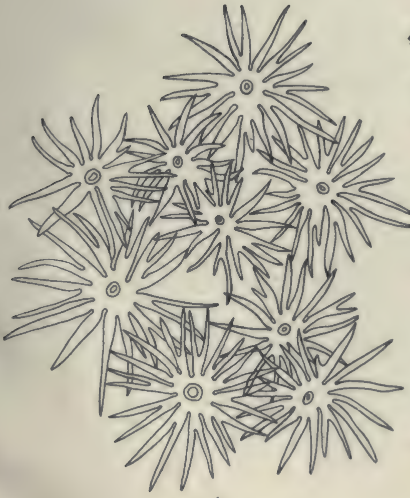

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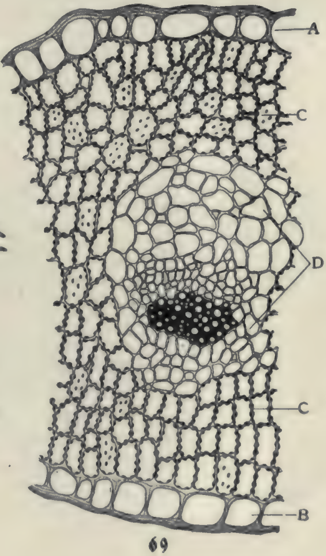

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